FEDERAL AID TO FISH RESTORATION

COMPLETION REPORT

NATURAL LAKES INVESTIGATIONS

PROJECT NO. F-160-R

Study 7013. Evaluation of special regulations for managing walleye in Iowa's natural lakes

- Job 1. Population dynamics of adult walleye in Spirit Lake, East and West Okoboji Lakes, Clear Lake, Storm Lake, and Blackhawk Lake
- Job 2. The biological characteristics of Spirit Lake, East and West Okoboji Lakes, Clear Lake, Storm Lake, and Blackhawk Lake
- Job 3. Factors affecting the success or failure of special regulations used for managing walleye populations in natural lakes in Iowa
- Job 4. Completion report and management guidelines

Period covered: 1 July 1995 – 30 June 2005
Iowa Department of Natural Resources
Jeffery R. Vonk, Director

December 2005

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Study 7013. Evaluation of special regulations for managing walleye in Iowa's natural lakes

Period covered: 1 July, 1995 – 30 June, 2005

Prepared By:	Fisheries Research Biologist	12/22/05 Date
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Approved By:	Fisheries Research Supervisor	12/22/05 Date

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OBJECTIVE

By the year 2000, develop guidelines for managing walleye in natural lakes with special regulations such as bag limits, minimum length limits, maximum length limits, and slot limits

JOB 1.

Population dynamics of adult walleye in Spirit Lake, East and West Okoboji Lakes, Clear Lake, Storm Lake, and Blackhawk Lake

OBJECTIVE

By the year 2004, estimate the abundance, growth, mortality, harvest and exploitation of adult walleye in Spirit Lake, East and West Okoboji Lakes, Clear Lake, Storm Lake, and Blackhawk Lake

JOB 2.

The biological characteristics of Spirit Lake, East and West Okoboji Lakes, Clear Lake, Storm Lake, and Blackhawk Lake

OBJECTIVE

By the year 2004, determine the species diversity, current forage base, and other unique biological characteristics of each of the study lakes

JOB 3:

Factors affecting the success or failure of special regulations used for managing walleye populations in natural lakes in Iowa

OBJECTIVE

By the year 2004, classify all natural lakes with fishable populations of walleye according to their unique biological characteristics, and determine the relationship between these classifications and the potential success or failure of various special regulations

JOB 4:

Completion report and management guidelines

OBJECTIVE

To compile, analyze, and publish findings

COMPLETION REPORT
Research Project

STATE: Iowa

JOB Nos: 4

TITLE: Evaluation of special regulations for managing walleye in Iowa's natural Lakes

ABSTRACT - Spirit Lake, East and West Okoboji Lakes, Clear Lake, Storm Lake, and Blackhawk Lakes all support important walleye fisheries. In addition, all of these lakes (with the exception of Blackhawk Lake) are the main source of broodstock walleye for the Spirit Lake Hatchery. The densities of walleye in these lakes were not sufficient to meet demands of anglers or satisfy needs of the Spirit Lake Hatchery. This investigation examined the reasons why densities of walleye were lower than desired, and provided recommendations to increase densities of walleyes in these lakes. Inconsistent recruitment, not the angler, was the primary reason for low densities and harvests of walleye in these lakes. The current minimum length limits decreased walleye harvest but did not increase broodstock densities sufficiently. A 17-22 inch protected slot limit would increase densities of broodstock walleye in these lakes and allow needed harvest of higher density, slower growing immature fish.

Introduction

Spirit, East Okoboji, and West Okoboji lakes are part of an interconnected chain of glacial lakes, along the Iowa-Minnesota border known as the Iowa Great Lakes. The Iowa Great Lakes region is a popular vacation area with over one million visitors each year. Walleyes Stizostedion vitreum are popular gamefish in these lakes, and each year 30%-50% of the anglers specifically fish for walleyes even though walleyes constitute less than 1% of the total harvest of fish (Larscheid 1994).

Natural reproduction of walleye in the Iowa Great Lakes is extremely limited (Rose 1955; McWilliams 1976; McWilliams and Larscheid, 1992) and so these fisheries have been sustained by annual stockings of sac-fry and fingerlings. Despite these stockings, population densities and harvests of walleye in these lakes have declined (Larscheid 1995).

Besides being important walleye fisheries, these lakes are the main source of broodstock walleye (> 17 inches TL) for the Spirit Lake Hatchery. Due to increasing demands for more walleye, the production of the hatchery was expanded by 50% in 1978 to a capacity of 840 quarts of eggs. Beginning in 1980, the number of quarts of walleye eggs taken from these lakes declined and concern was raised about the possible decline in broodstock abundance (McWilliams 1990). Since 1987, additional eggs were obtained from Clear and Storm Lakes to offset these shortages.

In response to the increased demand for more walleye production, restrictive walleye regulations were imposed on the Iowa Great Lakes, as well as, Clear, and Storm lakes. Beginning in 1987, a minimum length limit of 14 inches was imposed on the Iowa Great Lakes. In 1991, a 15-inch minimum length limit was imposed on Storm Lake, and a 14-inch minimum length limit was imposed on Clear Lake. The daily bag limit was reduced from 5 to 3 fish per day, and the possession limit was reduced from 10 to 6 fish. Only one walleye could be greater than 20 inches in length, except in Storm Lake where only one walleye could be over 22 inches in length. Additionally, beginning in 1994, a minimum length limit of 15 inches was implemented on Blackhawk Lake, and the daily bag limit was again reduced from 5 to 3 walleye per day.

The goals of these regulations were to increase yield (lbs/acre), spread out the harvest to more anglers, increase catch rates, decrease harvest of small fish, decrease mortality of sub-legal walleye, and, ultimately, increase the number of large, especially broodstock, walleye in these lakes.

Larscheid (1995) concluded that the special walleye regulations implemented on the Iowa Great Lakes did not produce the desired changes in the adult walleye populations. Adult walleye densities continued to decline, broodstock densities were below the study objectives, and must be increased 2-4 times to reach the management objectives. Walleye harvest was among the lowest ever recorded in these lakes.

Exploitation of broodstock walleye was substantial and accounted for a significant portion of the total harvest of walleye. The regulation had shifted the harvest from the smaller immature fish to the larger broodstock fish. Yield of walleye did not increase nor did catch rates, including sub-legal fish. Densities of sub-legal walleyes did not increase as a result of the length limit, and in fact decreased dramatically. Walleye harvest statistics in the Okoboji Lakes were considered to be excellent prior to the implementation of the length limit in 1987; however, since the length limit was imposed, the quality of the walleye fishing in the Okoboji Lakes declined dramatically.

The reduction in the bag limit from five to three walleye per day was not effective in either reducing or spreading out the walleye harvest to more anglers. The harvest would have been the same if no regulation were in effect. To be effective this regulation would have to be lowered to one fish per day, which would not be acceptable to anglers. Similar results were obtained when we looked at creel data from the Mississippi River, Clear Lake, Storm Lake, and Lake Rathbun. The one walleye over 20 inches was not effective in either reducing or spreading out the harvest of large walleye. The same number of large walleye would have been harvested with or without this regulation.

Larscheid (1995) concluded that the current special regulations implemented on the Iowa Great Lakes will continue to hamper the recovery, rather than aid the recovery of the broodstock populations. The lesson we learned from previous research on these lakes (F-135-R) was that special regulations are not a panacea for managing walleyes, and in fact, more harm than good may be the result of such regulations. However, special regulations are popular to anglers and fishery managers alike, and there is a large contingency that would like to implement statewide walleye length limits, reduced bag limits, and special regulations such as the one fish over 20 inches in length. Research is needed to determine the benefit of the current special regulations being used, and the impact of special regulations might have on other natural lake fisheries. The end result of this study will be the development of a comprehensive plan for management of walleye populations in Iowa's natural lakes. This plan will address both stocking and regulation of harvest.

Description of study areas

Spirit Lake, and East and West Okoboji lakes are located in Dickinson county, Iowa, and are part of an interconnected chain of glacial lakes along the Iowa-Minnesota border that collectively form the Iowa Great Lakes (Figure 1). These lakes are extremely productive and all commonly have dense algal blooms late in the summer. The littoral zones in these lakes usually have well developed stands of curlyleaf pondweed Potamogeton crispus, sago pondweed Potamogeton pectinatus, northern watermilfoil Myriophyllum exalbescens, and coontail Ceratophyllum demersum.

Currently there are at least 47 species of fish in these lakes with excellent fisheries for walleye, smallmouth bass Micropterus dolomieu, largemouth bass Micropterus salmoides, northern pike Esox lucius, muskellunge Esox masquinongy, channel catfish Ictalurus punctatus, black bullhead Ictalurus melas, bluegill Lepomis machrochirus, and yellow perch Perca flavescens.

Spirit Lake is Iowa's largest natural lake with 5,650 surface acres and a maximum depth of 24 feet. The basin is bowl shaped with gradually sloping shores and extensive muck flats and few rocky reefs. Spirit Lake flows into East Okoboji Lake by a narrow channel located near the Spirit Lake Hatchery (Figure 1). East Okoboji Lake is a long, narrow and shallow lake with 1,835 surface acres and a

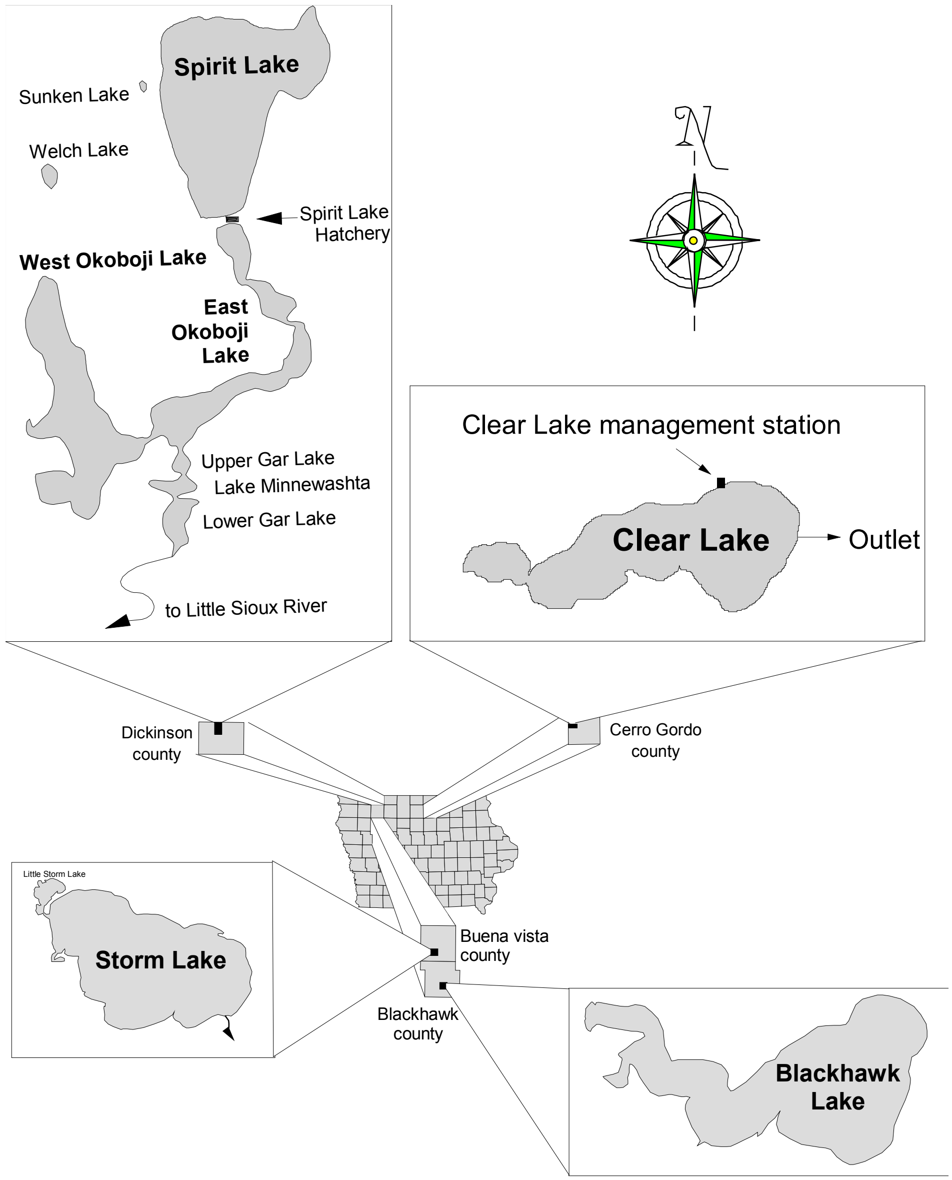

Figure 1. The study areas, showing the location of the Iowa Great Lakes, the Spirit Lake Fish hatchery, Storm, and Blackhawk lakes.

maximum depth of 22 feet. East Okoboji also has extensi ve muck flats (particularly in the northern portions of the lake), few rocky reefs, and is connected to West Ok oboji Lake by a narrow channel in the southern portion of lake (Figure 1). West Okoboji Lake is Iowa's second largest natural lake with 3,847 surface acres and is Iowa's deepest natural lake with a maximum depth of 136 feet. In contrast to Spirit and East Okoboji Lakes, West Okoboji thermally stratifies in summer and usually does not have extensive algal blooms. The basin in West Okoboji Lake is steep sided with extensive rocky reefs and cobble shoreline.

Clear Lake is a shallow eutrophic lake with about 3,600 surface acres and is located in Cerro Gordo county, Iowa (Figure 1). Clear Lake has a maximum depth of 19 feet and has extensive muck flats and few rocky reefs. Due to poor water clarity, Clear Lake generally does not have stands of aquatic vegetation. However, dense stands of the giant bulrush (Scirpus validus) are present particularly along the northern shoreline. Yellow bass (Morone mississippiensis), black bullheads, and walleyes are the most abundant game fish harvested, although some northern pike, muskellunge, crappie, and yellow perch are also taken.

Storm Lake, located in Buena Vista county (Figure 1), is a large, shallow eutrophic lake with approximately 3,000 surface acres and a mean depth of 6.0 feet. Blackhawk Lake, located in Sac County (Figure 1), is 925 surface acres with a maximum depth of only 12 feet. Water clarity in these lakes is usually very poor due to excessive wave action, heavy boat traffic, and carp. These lakes generally have extensive blooms of blue-green algae in the summer, and few (if any) beds of aquatic vegetation. Gizzard shad are abundant in both Blackhawk and Storm lakes and are the primary forage for walleyes.

Methods

Sampling broodstock walleye

Gill nets were used to collect broodstock walleye from Spirit Lake, and East and West Okoboji lakes, Clear Lake, and Storm Lake. The fish were spawned, measured to the nearest tenth of an inch, marked by inserting a Visual Implant tag (VI; Bergman et al., 1992) just below the skin on the lower jaw (Figure 2), and released in the same lake as captured. Each VI tag had a unique number so that individual fish could be identified. Broodstock walleye were also marked by removing the first two dorsal fin spines, and with a caudal fin punch.

In the Iowa Great Lakes, adult walleyes were also sampled at night with boat-mounted AC electrofishing gear.

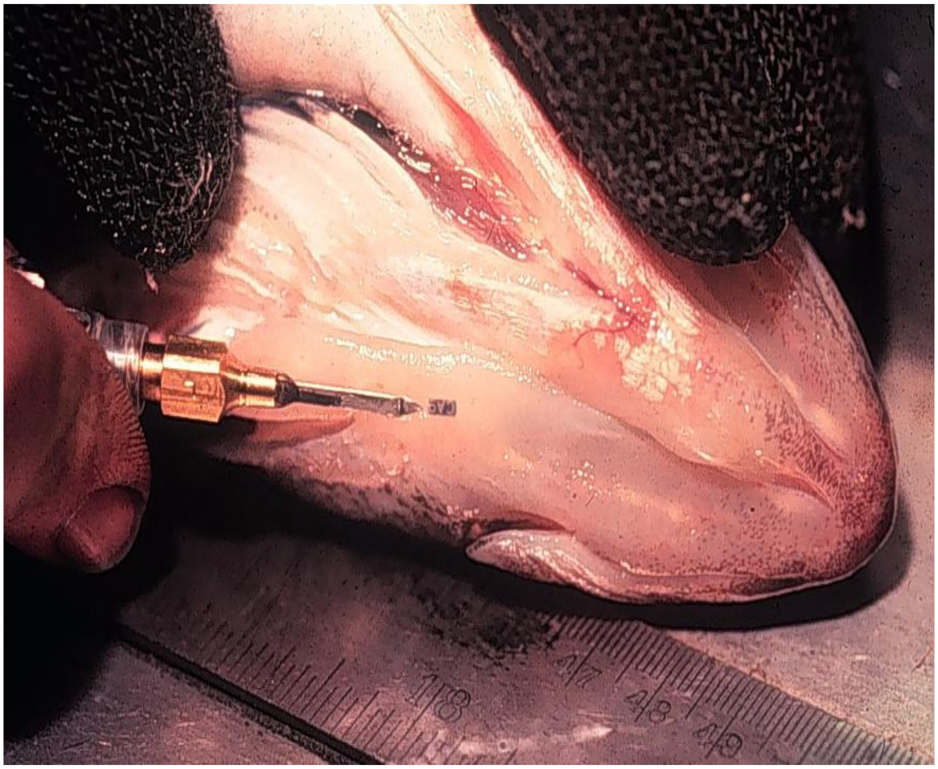

Figure 2. Method of injecting Visual Implant tags underneath the clear tissue on the lower mandibles of walleyes.

Sampling was concentrated around known spawning shoals and rocky points to maximize the number of walleyes captured. All walleyes captured were examined for marks, measured to the nearest tenth of an inch, weighed to the nearest hundredth of a pound, marked with a caudal fin punch, and released near the point of capture. Walleye CPUE, expressed as number of walleye sampled per hour of electrofishing, was used as an index of walleye abundance.

Analyses of tag returns

A reward system (pre assigned by tag number) and an intensive advertising program were used from 1990-1995 to increase voluntary returns of the tags from anglers. Rewards varied from a subscription to the Iowa Conservationist magazine to $100. Posters and bulletins explaining the program were placed at informational booths around the lakes and at local bait shops. To be eligible for a reward, the anglers were required to return the tag and fill out a questionnaire. These questions were summarized to yield information as to angler satisfaction with the current regulations, walleye movement between lakes, growth of tagged walleye, tag visibility, and angler awareness of the tagging program. The reward program was discontinued in 1996 and a voluntary program was initiated.

The reported ratio, or the fraction of the tags reported by anglers, was estimated as the actual number of tags returned by anglers divided by the estimated number of tagged fish caught. The apparent rate of exploitation and/or the apparent size of the population based on tag returns may be seriously biased if the reported ratio is low (Paulik 1961); therefore, recaptures of tagged broodstock walleye were adjusted by dividing the actual number of recaptures by the reported ratio (Ricker 1975).

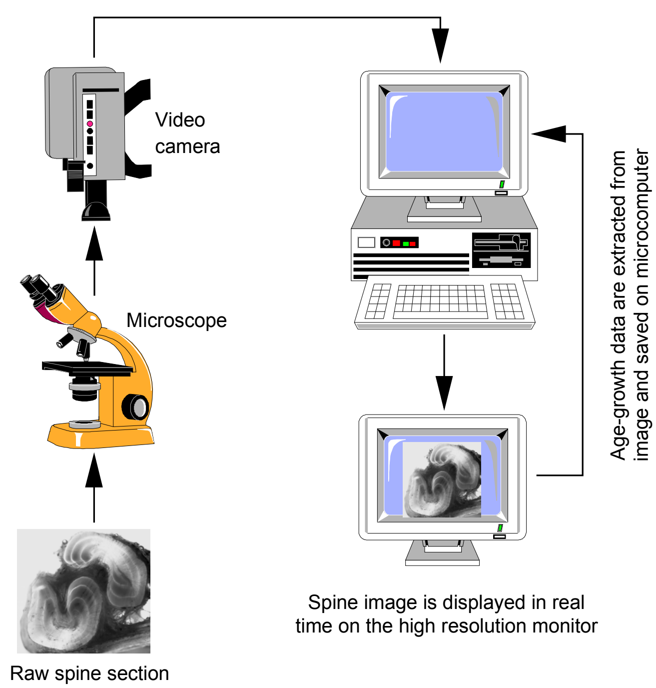

Figure 3. A schematic diagram of the Optimas image analysis system.

Exploitation of broodstock walleye was estimated as a ratio of the estimated number of broodstock walleye caught by the total number of broodstock walleye tagged. Broodstock walleye densities (> 17 inches in length) were calculated with the Jolly-Seber model (an open population model; Seber 1982. The Jolly-Seber model was also used to estimate the annual total mortality of broodstock walleye. Total annual fishing mortality was subtracted from total mortality to estimate natural mortality (Ricker 1975). In the spring, broodstock walleye intermingle in the Okoboji Lakes (McWilliams 1983), and were, therefore, treated as one stock for analytical purposes.

Age-growth of walleye

Dorsal fin spine sections were used to estimate the age of broodstock walleye. Dorsal fin spines were sectioned in approximately 1/4 inch sections using a homemade saw fitted with a Dremel saw blade (Margenau 1982). Spine sections were placed on a g lass slide, cleared with glycerin and viewed with a compound microscope (30x) using reflected light (Figure 4).

All age-growth information from these spines and otoliths were measured and saved to disk with the Optimas image analysis system (Biosonics inc., Seattle WA). The Optimas system consists of a microscope, video camera, video frame grabber, high resolution monitor, and a pentium personal computer (Figure 4). A video image is acquired with the video camera through the microscope. This image is translated by the frame grabber into a digital image which is then displayed in real-time on the high resolution monitor. This image can then be manipulated with the Optimas software which automates the recording of the age-growth information.

Creel survey

Each year, an expandable creel survey was conducted on these lakes using the methods outlined in Rose (1956). Completed trip information were obtained from boat, shore, and ice anglers. Species sought, miles traveled to lake, and angler expenses were also recorded. Expenses

Figure 4. Section of the second dorsal fin spine of a 6 year-old female walleye. The numbers correspond to annuli. This walleye was marked when stocked with a freeze brand and so is a known-age walleye.

included the amount of money the angler spent that day to go fishing (e.g. gas, bait, etc.), but did not include long term investments in fishing accessories (e.g. boats, motors, etc.). Using historic creel data, the effects of the current walleye harvest restrictions were assessed.

Population modeling

The Generalized Inland Fisheries Simulator Model (GIFSIM) was used to model the impact of various stocking regimes and special harvest restrictions on the walleye populations in Spirit and the Okoboji Lakes. The input to the model was based on data collected during this study period (age-growth, length-weight relationships, fishing mortality, natural mortality, seasonal trends in exploitation, etc.). A total of 30 years were simulated and the last 15 years were averaged to predict harvest and abundance of walleye. The accuracy of these predictions were assessed by comparing these predictions to the actual data collected since 1987.

Results

Age-growth of walleye

A total of 3,005 walleyes from Spirit Lake were aged using dorsal fin spine sections (Table 1). On average, it took 3-4 years for walleye to recruit into these fisheries (14 inches) and 4-5 years to recruit into the broodstock population. The typical male in Spirit Lake would reach a maximum length of 23 inches, whereas, a typical female walleye would exceed 28 inches (Table 1).

Walleye growth was similar in the Okoboji lakes. A total of 1,383 walleyes from the Okoboji lakes were aged using dorsal fin spine sections (Table 2). On

Table 1. Average back-calculated lengths (TL in inches) and Von Bertanlanffy (Von Bert) growth coefficients of walleyes in Spirit Lake, 1998-2004 (combined).

Age	Male walleyes			Female walleyes			All walleyes		
	Average	n	SD	Average	n	SD	Average	n	SD
1	4.7	1,457	0.8720	4.8	1,548	0.8604	4.8	3,005	0.8664
2	9.3	1,457	1.6805	9.5	1,548	1.7588	9.4	3,005	1.7250
3	12.8	1,445	1.5839	13.3	1,547	1.7873	13.1	2,992	1.7128
4	15.2	1,340	1.5739	16.4	1,544	1.8932	15.8	2,884	1.8480
5	17.2	1,197	1.3638	18.9	1,454	1.7244	18.1	2,651	1.7946
6	18.5	920	1.3011	20.7	1,029	1.6933	19.7	1,949	1.8521
7	19.5	662	1.2123	22.1	644	1.6049	20.8	1,306	1.9181
8	20.3	366	1.2548	23.5	359	1.5782	21.9	725	2.1476
9	20.9	203	1.3051	24.5	196	1.4988	22.7	399	2.2953
10	21.3	106	1.3616	25.3	123	1.3510	23.4	229	2.3933
11	21.5	49	1.0522	25.9	81	1.2815	24.2	130	2.4643
12	21.7	25	0.9413	26.3	40	1.2672	24.5	65	2.5463
13	22.5	9	1.0543	26.8	20	0.9434	25.5	29	2.2209
14	22.6	3	1.6819	27.2	10	1.0425	26.2	13	2.3254
15	23.7	2	1.8385	27.3	5	1.1184	26.3	7	2.1059
16				28.3	2	0.1414	28.3	2	0.1414
Von Bert model	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**
$L_{infinity}$	23.09	0.2369	0.9959	28.37	0.0608	0.9999	26.93	0.0039	0.9973
K	0.27	0.0133		0.23	0.0019		0.22	0.0001	
T_o	0.13	0.0900		0.18	0.0156		0.03	0.0014	

Table 2. Average back-calculated lengths (TL in inches) and Von Bertanlanffy (Von Bert) growth coefficients of walleyes in the Okoboji lakes, 1998-2004 (combined).

Age	Male walleyes			Female walleyes			All walleyes		
	Average	n	SD	Average	n	SD	Average	n	SD
1	5.1	525	0.9019	5.1	858	0.8596	5.1	1,383	0.8756
2	9.3	519	1.2779	9.5	858	1.3202	9.4	1,377	1.3083
3	12.1	497	1.4424	12.8	858	1.5410	12.6	1,355	1.5421
4	13.4	447	3.3226	15.7	856	1.8181	14.9	1,303	2.6595
5	15.7	357	1.7625	18.3	834	1.9233	17.5	1,191	2.2114
6	17.2	298	1.8757	20.5	660	2.0022	19.5	958	2.4646
7	18.3	240	1.8772	22.2	409	2.1191	20.8	649	2.7750
8	19.2	161	1.8074	23.6	176	2.1336	21.5	337	2.9581
9	19.8	100	1.5944	24.5	100	2.0715	22.1	200	3.0069
10	20.3	69	1.4685	25.6	65	2.0152	22.9	134	3.1620
11	21.1	58	1.4254	26.3	40	1.4996	23.2	98	2.9393
12	21.8	48	1.4934	26.9	22	1.4081	23.4	70	2.7987
13	22.0	15	1.7684	27.1	5	2.2207	23.3	20	2.9093
14	22.2	7	1.6663	26.4	2	1.3696	23.1	9	2.4065
15	23.1	3	1.3466	25.8	1		23.8	4	1.7352
16	22.8	2	0.6364	26.2	1		23.9	3	2.0636
17				26.8	1			1	

Von Bert model	Estimate	SD	r^2	Estimate	SD	r^2	Estimate	SD	r^2
$L_{infinity}$	23.62	0.0105	0.9966	27.74	0.0001	0.9922	24.32	0.2024	0.9969
K	0.20	0.0003		0.24	0.0000		0.27	0.0107	
T_o	-0.32	0.0052		0.23	0.0000		0.17	0.0769	

average, it took 3-4 years for walleye to recruit into these fisheries (14 inches) and 4-5 years to recruit into the broodstock population. The typical male in the Okoboji lakes would reach a maximum length of nealry 24 inches, whereas, a typical female walleye would exceed 27 inches (Table 2).

A total of 222 walleyes from Clear Lake were aged using dorsal fin spine sections (Table 3). On average, it took 3-4 years for walleye to recruit into these fisheries (14 inches) and 4-5 years to recruit into the broodstock population. The typical male in Clear Lake would reach a maximum length of 24 inches, whereas, a typical female walleye would exceed 27 inches (Table 3).

Walleye growth was substantially faster in Storm and Blackhawk lakes (Tables 4-5). On average, it took 2-3 years for walleye to recruit into these fisheries (15 inches) and 3-4 years to recruit into the broodstock population. The typical male in Storm Lake would reach a maximum length of only 21 inches, whereas, a typical female walleye would exceed 31 inches (Table 4). The typical male in Blackhawk Lake would reach a maximum length of only 23 inches, whereas, a typical female walleye would exceed 28 inches (Table 5).

Population densities of broodstock walleye

In m ost years, broodstock densities were significantly below the study objectives in Spirit and the Okoboji lakes, average densities varying from 0.9 to 1.1 broodstock walleye per acre (Table 6). Based on these estimates, the broodstock walleye populations would have to be

Table 3. Average back-calculated lengths (TL in inches) and Von Bertanlanffy (Von Bert) growth coefficients of walleyes in Clear Lake, 2002.

Age	Male walleyes			Female walleyes			All walleyes		
	Average	n	SD	Average	n	SD	Average	n	SD
1	4.5	106	0.9621	5.2	116	1.1416	4.9	222	1.1134
2	10.1	106	1.9753	10.6	116	2.1020	10.4	222	2.0527
3	13.9	106	1.6924	14.5	116	2.1965	14.2	222	1.9942
4	15.9	98	1.5888	17.5	116	2.0160	16.8	214	1.9775
5	17.8	66	1.7121	19.7	106	1.8575	18.9	172	2.0191
6	19.2	50	1.6369	21.7	89	1.9624	20.8	139	2.2071
7	20.1	38	1.6803	23.0	67	2.0182	21.9	105	2.3410
8	21.2	30	1.4735	24.1	50	2.0477	23.0	80	2.3207
9	22.2	23	1.4927	24.9	42	2.0516	24.0	65	2.2868
10	22.2	10	1.5854	24.5	21	1.7790	23.8	31	2.0112
11	23.1	8	1.7370	25.1	16	1.0710	24.4	24	1.6028
12	23.7	6	1.2846	25.6	14	1.0679	25.0	20	1.4355
13	24.2	6	1.2903	26.2	13	1.0861	25.5	19	1.4484
14	23.9	3	0.4340	26.5	12	1.0966	26.0	15	1.4720
15	24.7	1		26.8	9	1.1136	26.6	10	1.2398
16				27.1	8	1.1541	27.1	8	1.1541
17				26.8	1				
18				27.3	1				
19				27.8	1				
20				28.2	1				
Von Bert model	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**
$L_{infinity}$	24.32	0.0001	0.9949	27.00	0.1826	0.9978	26.74	0.2789	0.9957
K	0.28	0.0000		0.28	0.0092		0.25	0.0121	
T_o	0.16	0.0000		0.21	0.0622		0.12	0.0954	

doubled to reach our objectives of 2 broodstock per acre in these lakes. Broodstock densities were more variable in Clear and Storm Lakes. Average densities varied from 1.5 fish per acre in Clear Lake to nearly 4 per acre in Storm Lake (Table 6).

Mortality estimates of broodstock walleye

Annual survival for broodstock walleye varied a great deal in each lake (Table 7). Total survival was similar for Spirit and the Okoboji lakes and averaged around 67%. Total annual survival was around 60% for Clear Lake and only 45% for Storm Lake. Exploitation of broodstock walleye from the Iowa Great Lakes was fairly consistent from 1990-1995 and varied from 16.7-17.4% in Spirit Lake, and from 13.7-27.8% in the Okoboji Lakes (Larscheid 1995). Exploitation f broodstock was significant and accounted for most of the walleye harvested (Larscheid 1992, 1993, 1994). On average, natural mortality exceeded fishing mortality of broodstock walleyes in the Iowa Great Lakes, but this difference was not significant.

Trends in walleye harvest and catch

The harvest of walleyes less than 14 inches declined dramatically since the implementation of the 14-inch length limit on the Iowa Great lakes (Figures 5-6). In fact, prior to the change in regulation, 45-46% of the walleye harvest was less than 14 inches. This decreased to 1%-2% after the minimum length limit was imposed (Figures 5-6). As can be seen in these graphs, we noted a dramatic shift of harvest from 2-4

Table 4. Average back-calculated lengths (TL in inches) and Von Bertanlanffy (Von Bert) growth coefficients of walleyes in Storm Lake, 2002.

Age	Male walleyes			Female walleyes			All walleyes		
	Average	n	SD	Average	n	SD	Average	n	SD
1	5.0	59	1.0070	5.0	87	1.0137	5.0	146	1.0076
2	11.5	59	1.6813	11.1	87	2.0353	11.3	146	1.9022
3	14.5	55	1.3542	14.9	87	1.8908	14.7	142	1.7092
4	16.0	53	1.3046	17.3	85	1.7081	16.8	138	1.6722
5	17.2	50	1.2820	19.0	83	1.6294	18.3	133	1.7270
6	18.3	40	1.4114	20.6	73	1.8210	19.8	113	2.0086
7	19.9	11	1.4331	22.8	39	1.5877	22.2	50	1.9757
8	19.9	5	1.3382	24.5	24	1.6910	23.7	29	2.3974
9	20.3	3	1.8214	25.8	20	1.4100	25.1	23	2.3637
10	21.5	2	1.9092	26.6	16	1.4473	26.0	18	2.1943
11				27.4	14	0.8786	27.4	14	0.8786
12				28.1	10	0.7063	28.1	10	0.7063
13				29.1	4	0.0577	29.1	4	0.0577
Von Bert model	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**
$L_{infinity}$	21.11	0.5584	0.9860	31.19	0.0024	0.9940	32.36	1.5046	0.9899
K	0.39	0.0484		0.19	0.0000		0.16	0.0212	
T_o	0.22	0.1583		-0.10	0.0007		-0.34	0.2432	

Table 5. Average back-calculated lengths (TL in inches) and Von Bertanlanffy (Von Bert) growth coefficients of walleyes in Black Hawk Lake, 1999.

Age	Male walleyes			Female walleyes			All walleyes		
	Average	n	SD	Average	n	SD	Average	n	SD
1	6.6	27	1.3337	7.3	51	1.4699	7.0	78	1.4463
2	12.5	27	1.3284	13.6	51	1.6065	13.2	78	1.5840
3	15.9	27	1.1643	17.6	51	1.5984	17.0	78	1.6669
4	18.7	11	1.4830	19.8	24	1.5549	19.4	35	1.5968
5	20.1	8	1.0850	21.9	19	1.6331	21.3	27	1.6890
6	21.2	5	0.8152	23.8	9	0.8118	22.8	14	1.4922
7	22.1	1		25.1	6	0.9376	24.7	7	1.4287
8				26.4	2	0.7071	26.4	2	0.7071
Von Bert model	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**	**Estimate**	**SD**	**r^2**
$L_{infinity}$	23.39	0.2628	0.9994	28.42	0.0671	0.9965	28.75	0.0310	0.9935
K	0.41	0.0172		0.31	0.0017		0.28	0.0007	
T_o	0.19	0.0414		-0.01	0.0144		-0.07	0.0067	

Table 6. Total annual abundance (N) of broodstock walleyes (≥ 17 in TL) in Spirit Lake, the Okoboji lakes, Clear Lake, and Storm Lake estimated using the Jolly-Seber population model.

Year	N	SE (N)	95% C.I		
Spirit Lake					
1991	4,210	912	2,423	-	5,997
1992	4,007	677	2,680	-	5,335
1993	4,636	794	3,079	-	6,192
1994	5,381	693	4,023	-	6,739
1995	3,059	399	2,276	-	3,841
1996	3,946	500	2,966	-	4,927
1997	12,050	1,743	8,634	-	15,466
1998	4,580	586	3,432	-	5,727
1999	9,440	1,219	7,051	-	11,830
2000	8,208	1,585	5,102	-	11,315
2001	7,216	1,526	4,225	-	10,206
2002	9,515	1,746	6,093	-	12,938
2003	11,863	2,860	6,258	-	17,468
2004	3,530	939	1,690	-	5,370
Average	**6,546**	**355**	**5,850**	-	**7,242**
Okoboji lakes					
1991	3,027	584	1,882	-	4,173
1992	2,620	384	1,868	-	3,372
1993	1,886	265	1,368	-	2,405
1994	3,364	401	2,578	-	4,150
1995	4,186	490	3,225	-	5,147
1996	5,608	699	4,238	-	6,977
1997	2,884	362	2,175	-	3,593
1998	2,277	251	1,785	-	2,770
1999	3,212	475	2,281	-	4,143
2000	6,949	1,542	3,927	-	9,970
2001	4,109	1,240	1,678	-	6,540
2002	27,768	9,540	9,070	-	46,465
2003	1,679	519	662	-	2,696
2004	2,549	1,056	479	-	4,619
Average	**5,151**	**708**	**3,764**	-	**6,539**
Clear Lake					
1996	14,002	3,541	7,061	-	20,943
1997	1,945	200	1,554	-	2,336
1998	1,373	120	1,138	-	1,609
1999	1,596	149	1,304	-	1,887
2000	2,513	249	2,024	-	3,002
2001	10,541	1,157	8,273	-	12,809
2002	5,461	727	4,036	-	6,887
Average	**5,347**	**545**	**4,279**	-	**6,416**
Storm Lake					
1998	8,845	2,005	4,915	-	12,776
1999	16,095	3,411	9,409	-	22,781
2000	17,659	4,001	9,818	-	25,501
2001	4,999	1,052	2,936	-	7,062
Average	**11,900**	**1,431**	**9,094**	-	**14,705**

Table 7. Total annual survival (S) of broodstock walleyes (≥ 17 in TL) in Spirit Lake, the Okoboji lakes, Clear Lake, and Storm Lake estimated using the Jolly-Seber population model.

Year	S(%)	SE (S)	95% C.I		
Spirit Lake					
1990	89.64%	15.11%	60.02%	-	119.27%
1991	34.94%	5.50%	24.15%	-	45.73%
1992	69.22%	7.97%	53.59%	-	84.85%
1993	98.77%	12.94%	73.41%	-	124.13%
1994	42.69%	5.34%	32.22%	-	53.16%
1995	58.32%	7.03%	44.54%	-	72.10%
1996	109.82%	13.54%	83.29%	-	136.35%
1997	37.54%	4.61%	28.49%	-	46.58%
1998	87.23%	10.78%	66.11%	-	108.35%
1999	84.24%	15.75%	53.36%	-	115.12%
2000	38.72%	8.69%	21.69%	-	55.75%
2001	55.69%	10.67%	34.78%	-	76.59%
2002	98.91%	21.86%	56.07%	-	141.76%
2003	38.36%	11.16%	16.49%	-	60.22%
Average	**67.43%**	**1.92%**	**63.67%**	-	**71.19%**
Okoboji lakes					
1990	57.80%	8.27%	41.59%	-	74.00%
1991	56.40%	7.08%	42.53%	-	70.28%
1992	46.75%	5.39%	36.18%	-	57.32%
1993	83.62%	8.81%	66.35%	-	100.89%
1994	79.21%	8.14%	63.26%	-	95.16%
1995	75.01%	8.82%	57.71%	-	92.31%
1996	44.74%	5.41%	34.15%	-	55.34%
1997	51.85%	6.23%	39.64%	-	64.07%
1998	65.54%	8.96%	47.97%	-	83.10%
1999	109.61%	23.90%	62.77%	-	156.45%
2000	45.28%	14.18%	17.49%	-	73.07%
2001	95.35%	31.87%	32.89%	-	157.80%
2002	20.53%	6.32%	8.15%	-	32.92%
2003	104.81%	45.11%	16.39%	-	193.23%
Average	**66.89%**	**3.73%**	**59.59%**	-	**74.19%**
Clear Lake					
1995	57.88%	8.05%	42.09%	-	73.66%
1996	31.12%	2.93%	25.38%	-	36.85%
1997	57.00%	4.47%	48.24%	-	65.76%
1998	65.24%	6.00%	53.48%	-	77.00%
1999	50.25%	4.70%	41.03%	-	59.47%
2000	102.17%	9.17%	84.19%	-	120.14%
2001	46.37%	6.20%	34.22%	-	58.52%
2002					
Average	**58.57%**	**1.74%**	**55.17%**	**-**	**61.98%**
Storm Lake					
1997	43.13%	8.09%	27.26%	-	58.99%
1998	61.44%	11.56%	38.78%	-	84.11%
1999	49.91%	10.16%	29.98%	-	69.83%
2000	19.79%	4.33%	11.30%	-	28.27%
Average	**43.57%**	**3.01%**	**37.66%**	-	**49.47%**

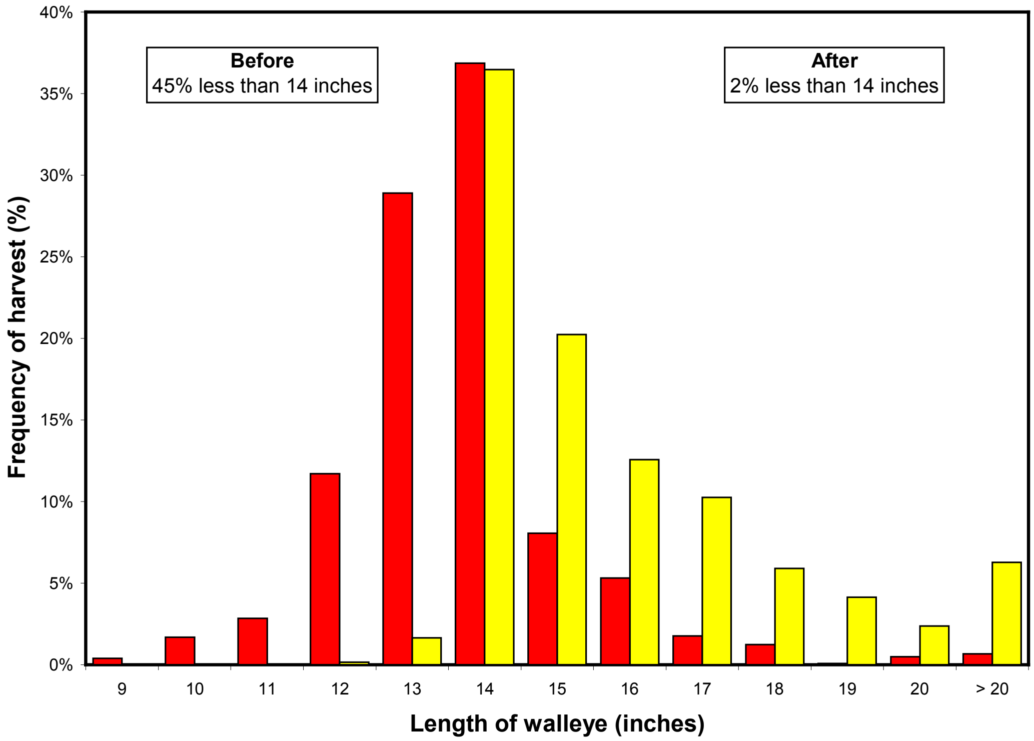

Figure 5 . The observed length frequency of walleye harvested from Spirit Lake both before (red bars; 1980, 1984-1986), and after (yellow bars; 1987-present) the minimum length of 14 inches was implemented.

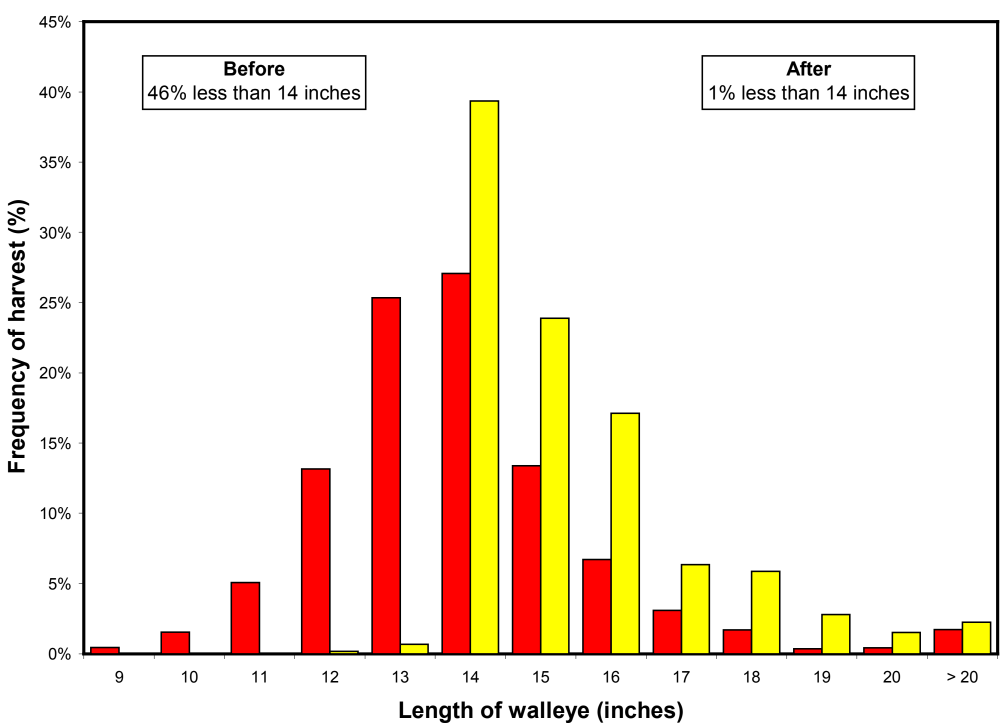

Figure 6 . The observed length frequency of walleye harvested from the Okoboji lakes both before (red bars; 1981-1983), and after (yellow bars; 1987-present) the minimum length of 14 inches was implemented.

year old fish to 5-7 year old fish. These same data also show compliance with the regulation was excellent, and very few sub-legal walleyes were harvested.

As expected, the total number of walleye caught by anglers (mostly sub-legal fish) increased dramatically following implementation of the length limit (Figures 7-8). It is also important to note that many anglers voluntarily released legal walleyes.

The probability of an angler harvesting a walleye from Spirit and the Okoboji lakes decreased significantly after we imposed the 14 inch minimum length limit in 1987 (Figures 9-10). However, when we considered only legal length fish, little differences were noted in the probability of harvesting walleye before and after the regulations were changed (Larscheid 1993).

Prior to the length limit, the probability of harvesting one walleye was 54% in Spirit Lake, and 75% in the Okoboji lakes (Figures 9-10). After the length limit was implemented the probability of harvesting at least one walleye decreased to 27% in Spirit Lake, and 29% in the Okoboji lakes. Similar but more dramatic trends were evident when comparing the probabilities of harvesting 2-3 walleyes from these lakes. For instance, the probability of harvesting three walleyes decreased 40% in Spirit Lake and 75% in the Okoboji lakes after the regulations were changed in 1987.

The reduction in the daily bag limit from five to three fish per day had little effect on the total numbers of walleye harvested from these lakes. In fact, if the reduction in the daily bag limit were in effect prior to the length limit change in 1987, the total harvest of walleyes would only have decreased about 8% in Spirit and 11% in the Okoboji lakes (Figures 11-12). To significantly reduce harvest, the daily bag limit on walleyes would have to be reduced to one fish per day, since most of the harvest is attributed to anglers harvesting only one walleye per trip (Figures 11-12).

The maximum length limit of one walleye over 20 inches, imposed in 1987, was ineffectual in reducing the numbers of large walleye harvested in these lakes (Figure 13). The same number of large walleyes would have been harvested with or without this regulation in effect. In fact, during the period from 1980-1994 not one angler was interviewed on Spirit and the Okoboji lakes that had more than one walleye over 20 inches in length (Larscheid 1995).

As expected, the numbers of walleye harvested in Spirit and the Okobojj lakes did not increase after the length limit was changed in 1987 (Figure 14). In fact, for a few years the harvest was at all time lows (1988-1993). Walleye harvest in Spirit and the Okoboji lakes moved up and down following the recruitment of the large 1986, 1991 and 1995 year-classes of walleyes.

Average weight of creeled walleye has increased since the implementation of the length limit on Spirit and the Okoboji lakes (Figure 15). In fact, broodstock walleyes now account for a substantial portion of the overall harvest in these lakes. This graph is another indication of the excellent compliance with the change in regulations.

Trends in number and weight of walleye harvested varied greatly after the regulations were changed in 1987 (Figure 14-16). No consistent trend was apparent and yield varied with the strength of the year-classes being harvested. The higher yields were the result of strong recruitment

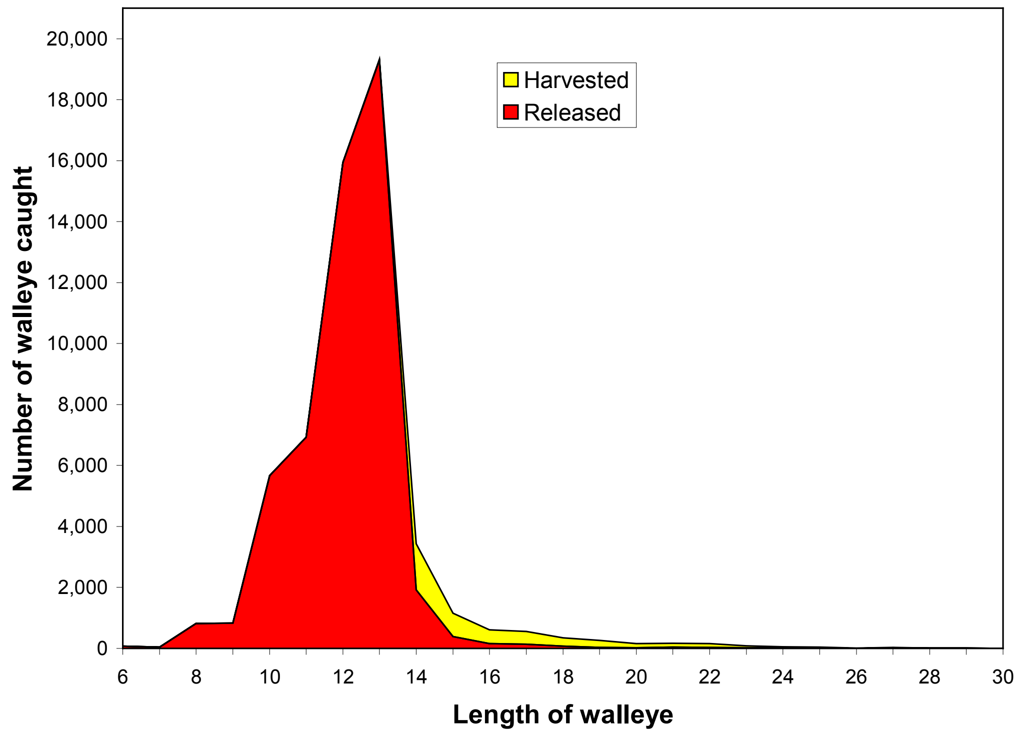

Figure 7 . The observed average length frequency of walleye caught from Spirit Lake, 1998-2004.

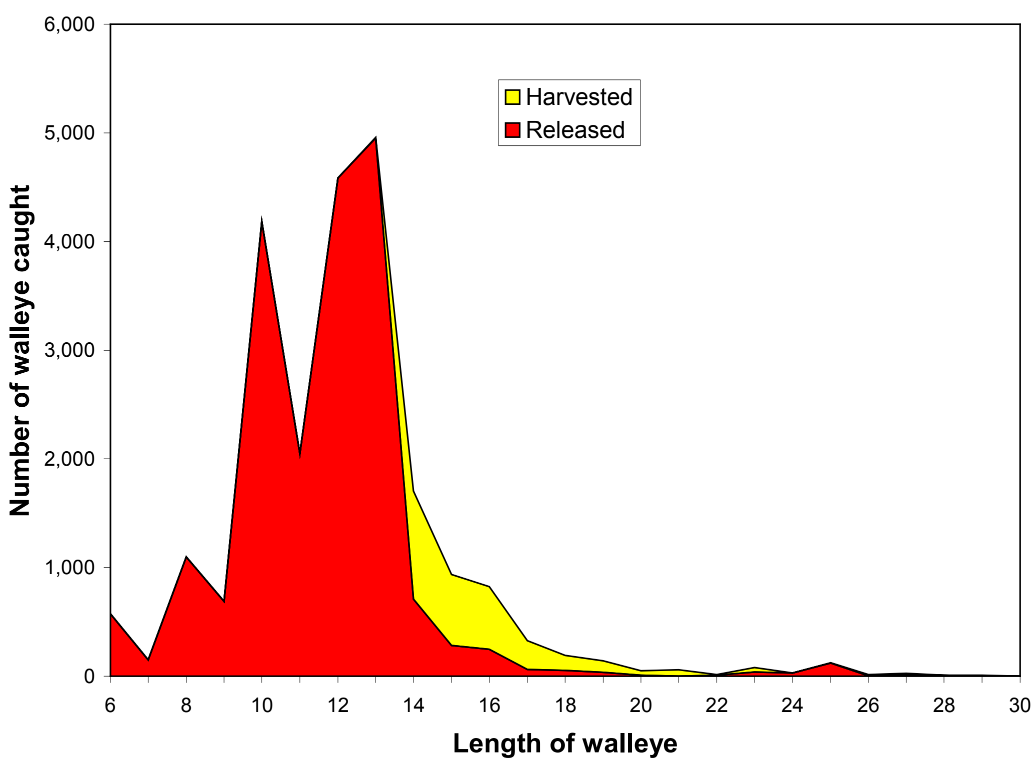

Figure 8 . The observed average length frequency of walleye caught from the Okoboji lakes, 1998-2003.

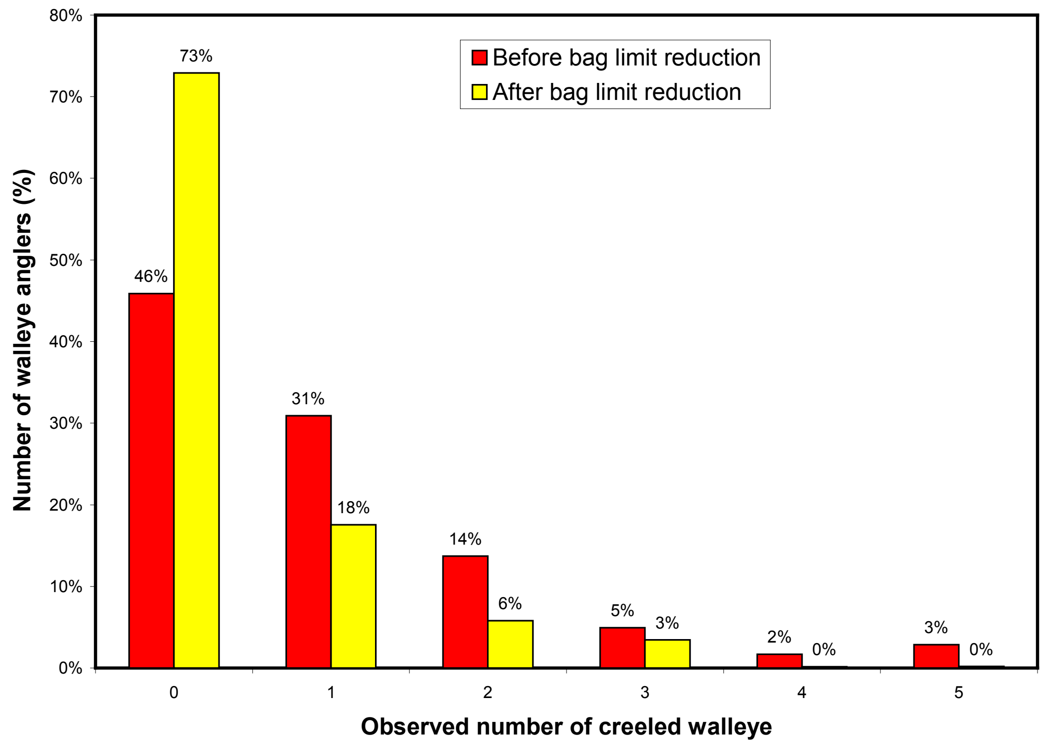

Figure 9. The number of walleyes harvested by anglers targeting walleyes in Spirit Lake, before (1980, 1984-1986) and after (1987-present) the bag limit was reduced from 5 fish to 3 fish per day.

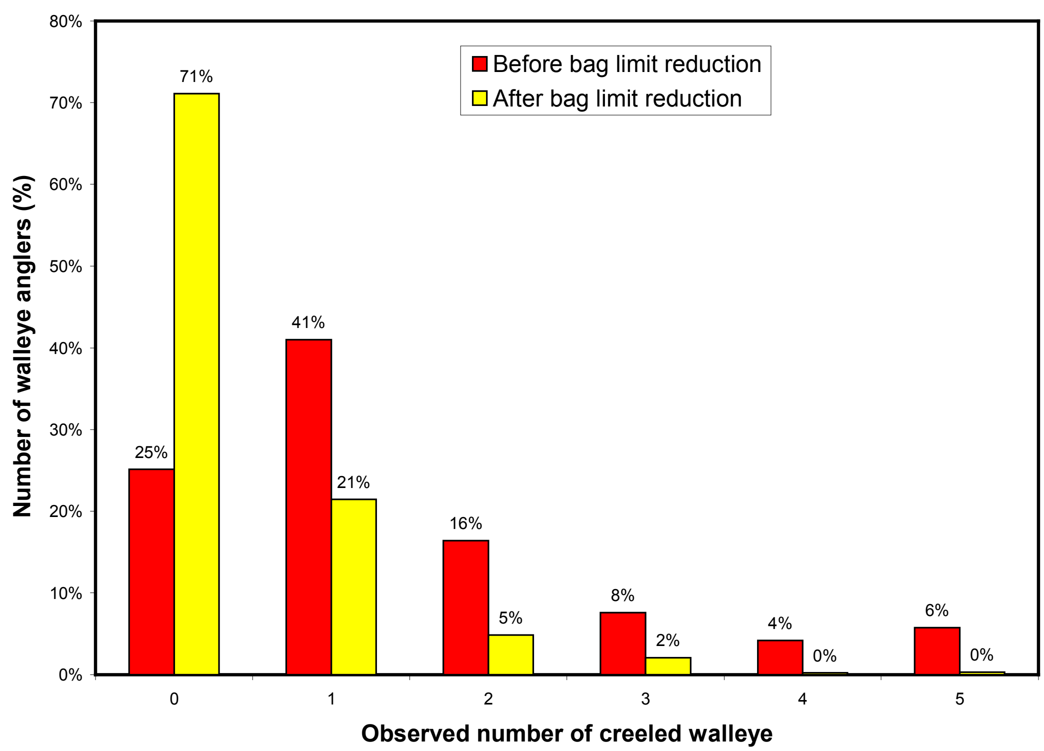

Figure 10. The number of walleyes harvested by anglers targeting walleyes in the Okoboji lakes, before (1981-1983) and after (1987-present) the bag limit was reduced from 5 fish to 3 fish per day.

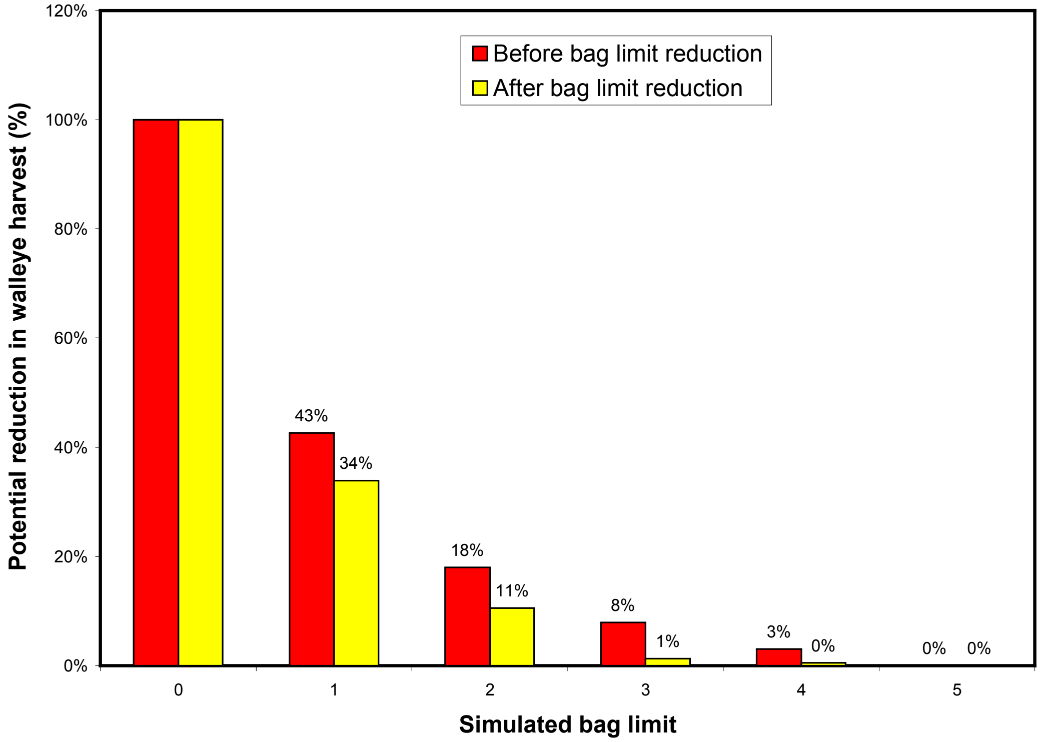

Figure 11. The potential reduction in walleye harvest that would be expected if a simulated bag limit were in place on Spirit Lake both before (1980, 1984-1986) and after (1987-present) the bag limit was reduced from 5 fish to 3 fish per day.

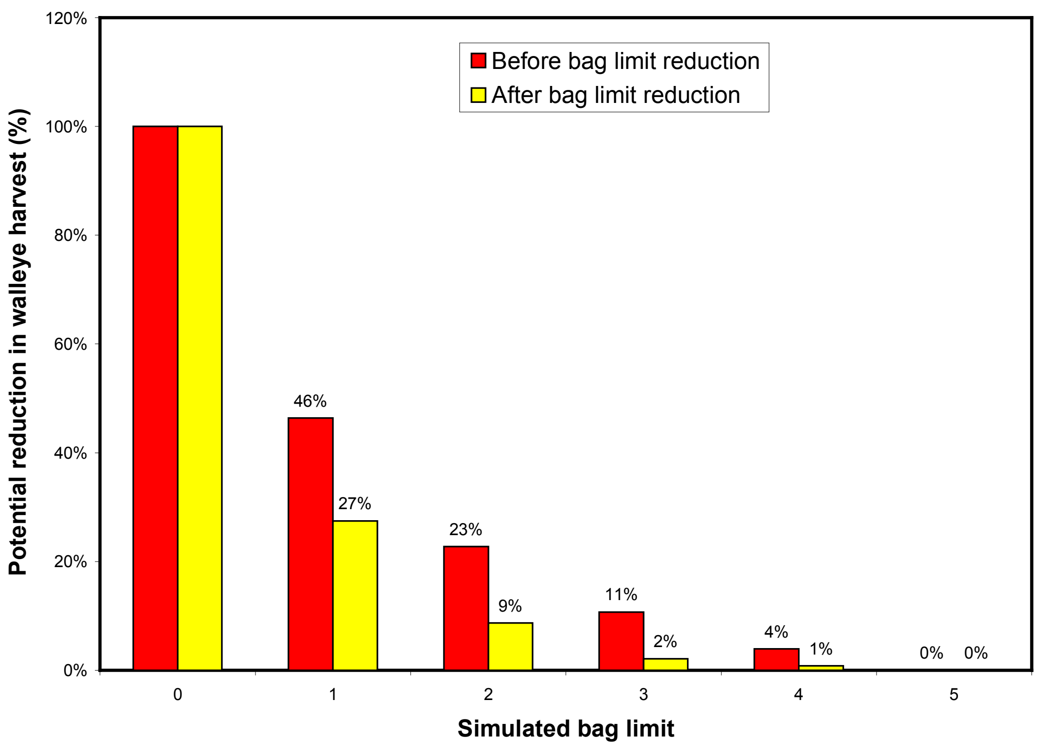

Figure 12. The potential reduction in walleye harvest that would be expected if a simulated bag limit were in place on the Okoboji lakes both before (1981-1983) and after (1987-present) the bag limit was reduced from 5 fish to 3 fish per day.

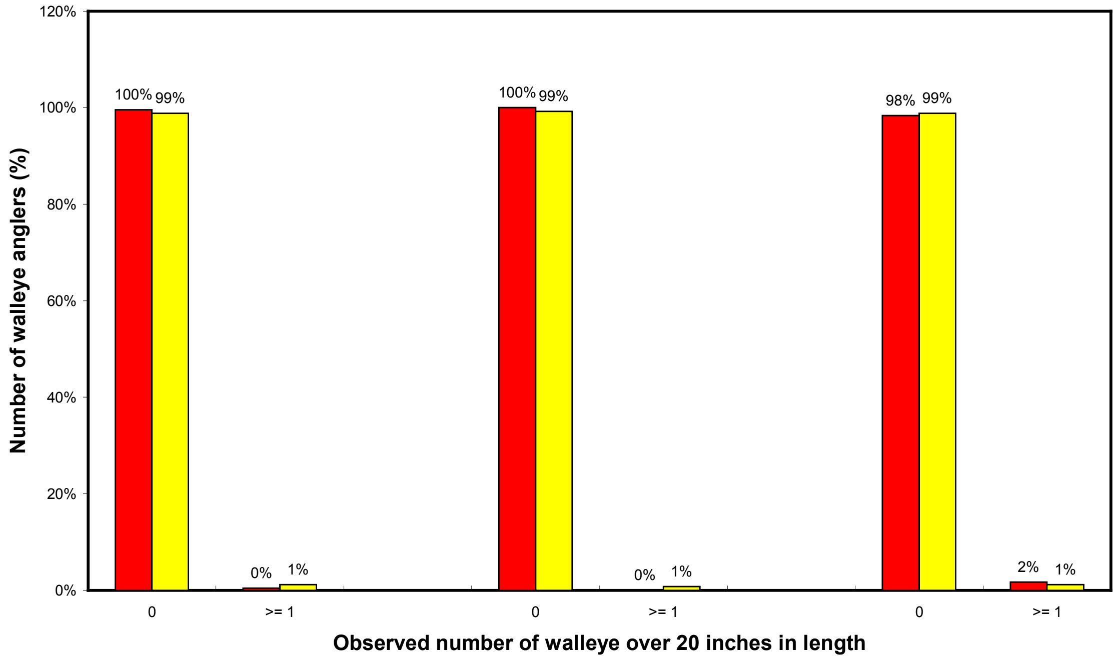

Figure 13. The observed number of walleye anglers with none or one or more walleyes over 20 inches in length at the completion of their fishing trips on Spirit and the Okoboji lake.

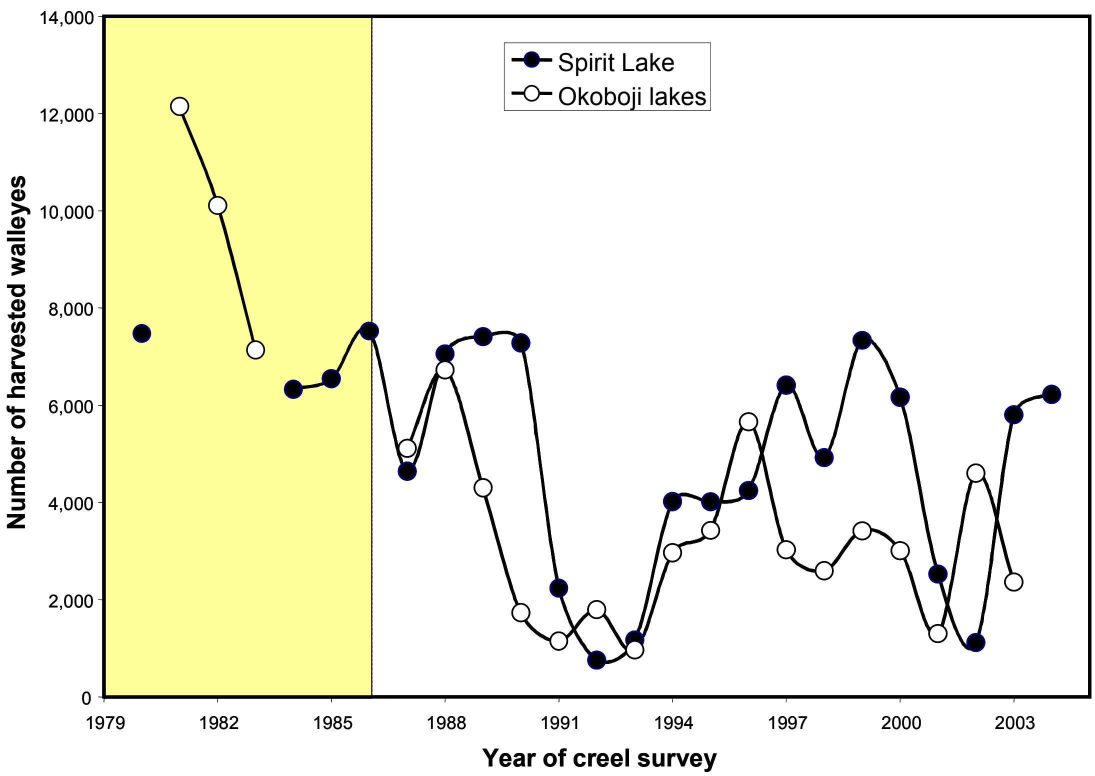

Figure 14. Total number of walleyes harvested from Spirit and the Okoboji lakes. The yellow part of the graph illustrates the years before the regulations were changed in 1986.

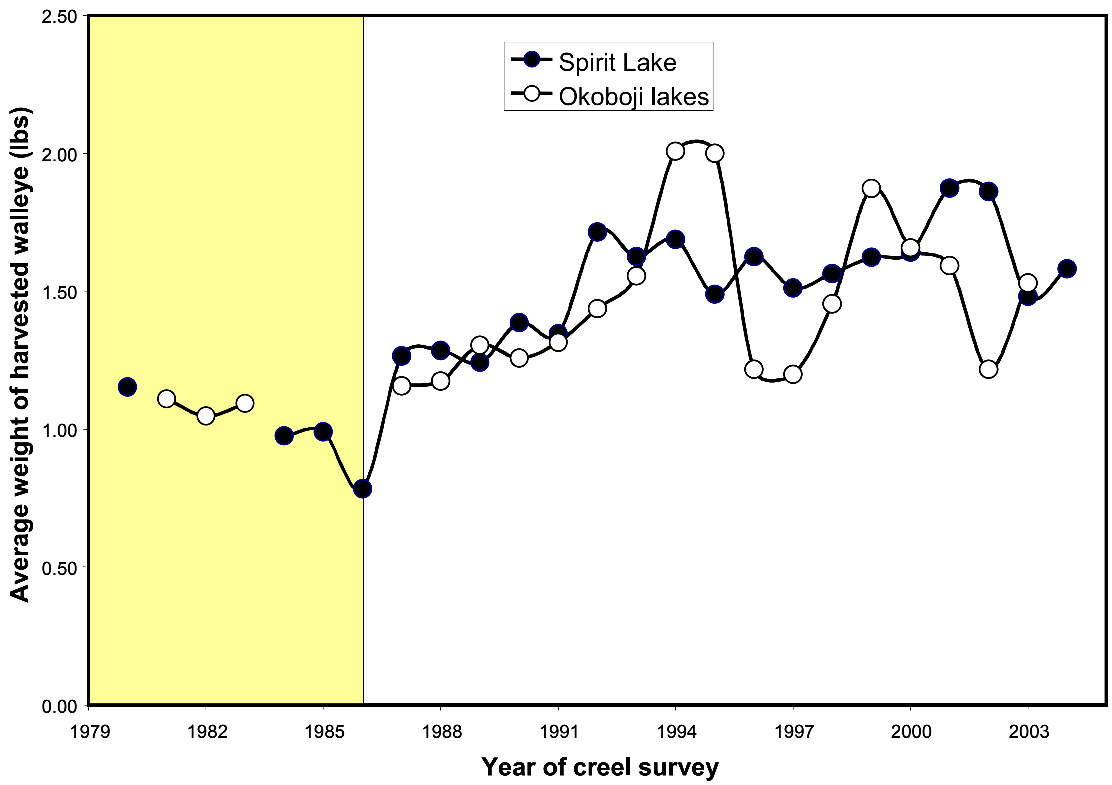

Figure 15. Average weight of walleyes harvested from Spirit and the Okoboji lakes. The yellow part of the graph illustrates the years before the regulations were changed in 1986.

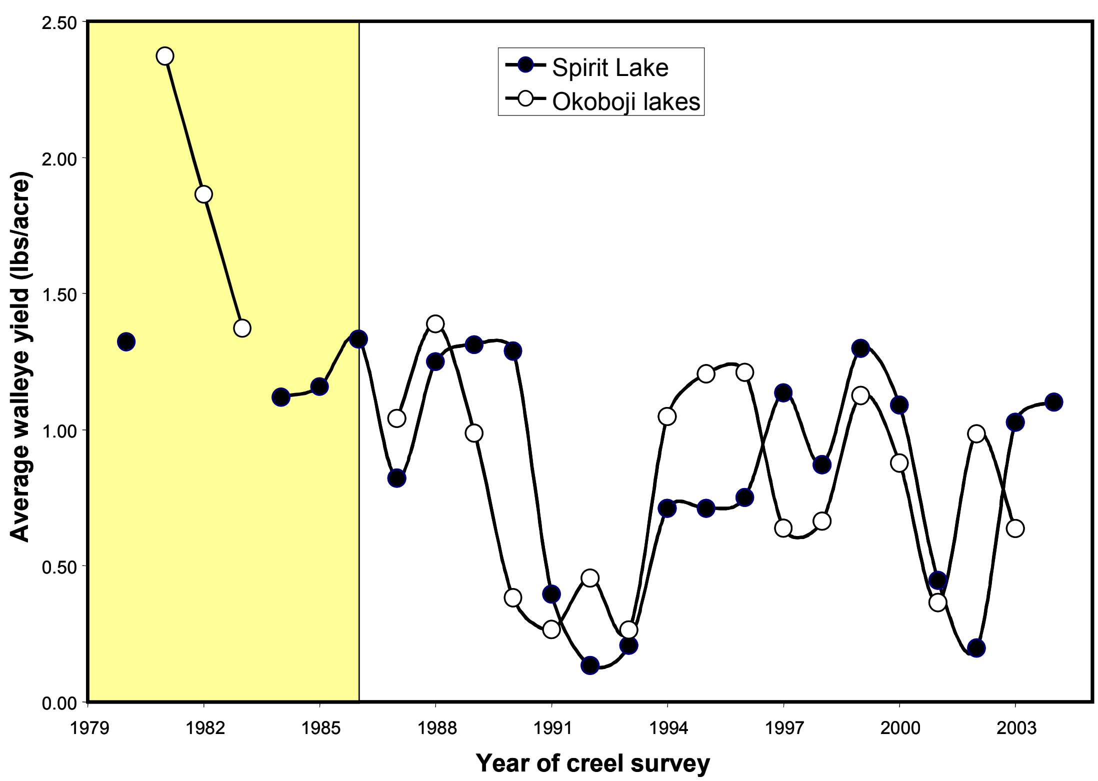

Figure 16. Average walleye yield (lbs/acre) from Spirit and the Okoboji lakes. The yellow part of the graph illustrates the years before the regulations were changed in 1986.

of the 1986, 1991, 1995, and 2001 year-classes of walleyes.

Though variable, due to abundance of fish in the various year-classes, harvest rates (# per hour) of walleyes appear to have declined in Spirit and the Okoboji lakes since the more restrictive regulations were imposed in 1987 (Figure 17). However, catch rates (mostly sub-legal fish) are, at present, extremely high due to a very strong year-class (2001) of smaller walleyes (Figures 7-8). Relative abundance of both sub-legal and legal walleyes have increased during our electrofishing surveys in Spirit and the Okoboji lakes (Figures 18-19). Again, these electrofishing trends are highly variable and reflects abundance of fish in each year-class.

Population modeling

Five special regulation scenarios were evaluated using the GIFSIM model. These were the 14, 16, and 18 minimum length limits, and two protected slot limits; 17-20 inches and 17-22 inches. Recruitment data were modified in the GIFSIM model to match observed patterns of recruitment in our study lakes.

Estimated mortality data (natural and exploitation) was used as starting points in the model. The mortality data were modified until the model produced results similar to current observed walleye harvest and population densities (Larscheid 1995). Overall, the simulations produced reasonable estimates of harvest and densities of walleye in these lakes. Therefore, all input parameters (growth, mortality, and recruitment) were retained and held constant in all subsequent modeling, and only special harvest regulations were changed. We applied this method to ascertain the potential impacts of a change in the walleye regulations in these lakes.

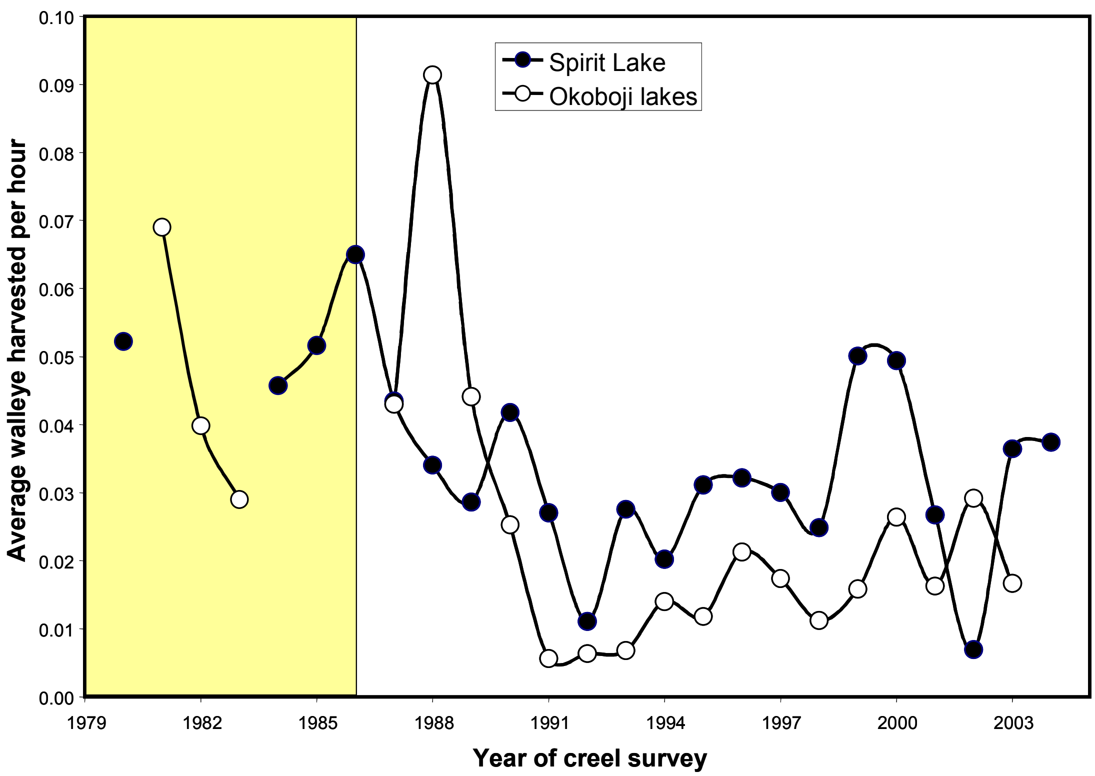

Figure 17. Average walleye harvest rates (#/hr) for by anglers fishing Spirit and the Okoboji lakes. The yellow part of the graph illustrates the years before the regulations were changed in 1986.

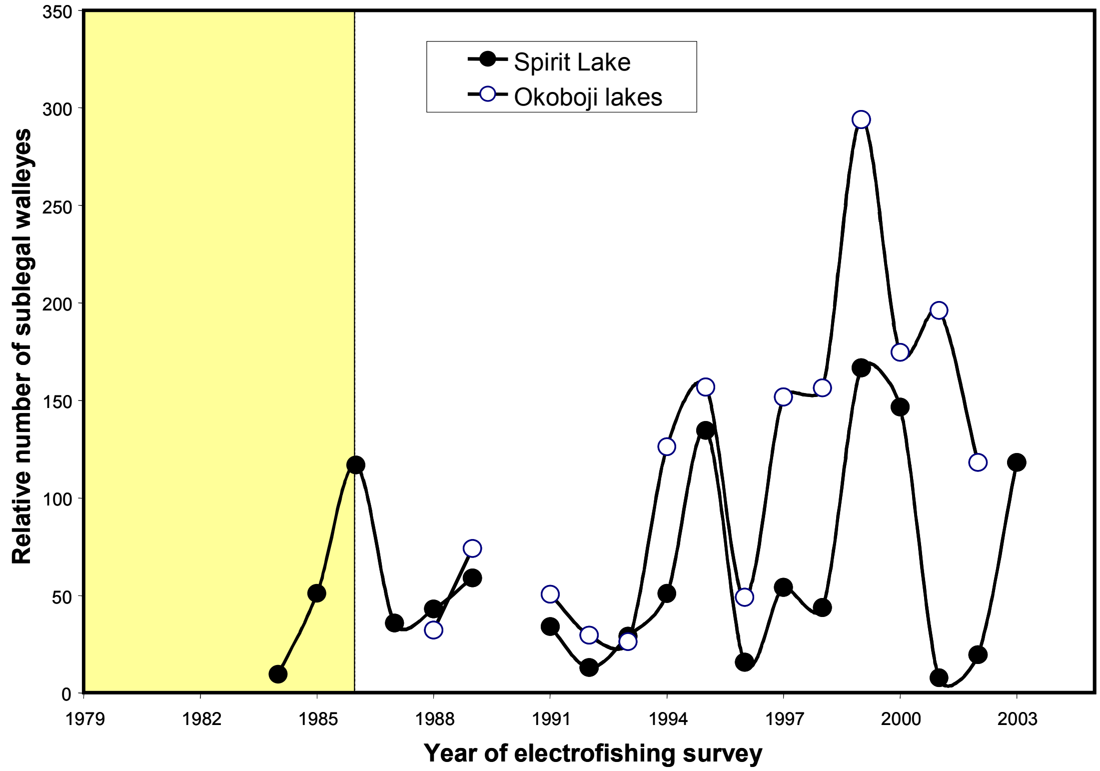

Figure 18. The relative number of sub-legal (< 14 inches TL) walleye in Spirit and the Okoboji lakes sampled with boat-mounted AC electrofishing gear. The yellow part of the graph illustrates the years before the regulations were changed in 1986.

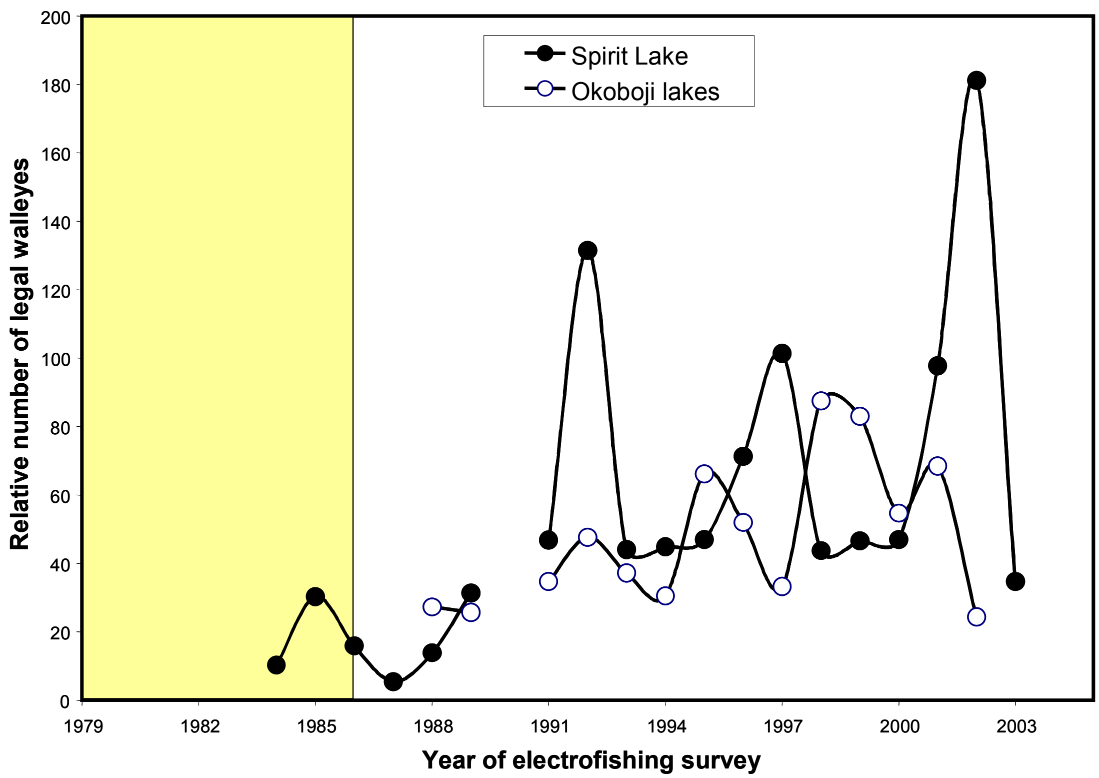

Figure 19. The relative number of legal (≥ 14 inches TL) walleye in Spirit and the Okoboji lakes sampled with boat-mounted AC electrofishing gear. The yellow part of the graph illustrates the years before the regulations were changed in 1986.

Before modeling, the potential impact of these special regulations was ascertained by looking at the percent of the age-classes (2-15) that would be protected by a special regulation. Spirit Lake will be used as an example to compare the relative impact of each regulation; similar impacts would be expected on our other study lakes.

A 14-inch minimum length limit would protect, on average, about 51% of the harvestable year-classes of walleye in Spirit Lake (Figure 20). These are mostly 2-3 year old fish, but some 4-6 year old fish (slower growing fish) would also be protected. A 16-inch minimum length limit would protect about 60% of the harvestable year-classes of walleye in Spirit Lake since more 4-6 year old fish would be protected (Figure 21). A 18-inch minimum length limit would protect about 68% of the harvestable year-classes of walleye in Spirit Lake since almost all age 4-5 year old fish and many 6-7 year old fish would be protected (Figure 22).

A protected slot of 17-20 inches would protect about 14% of the harvestable year-classes of walleye in Spirit Lake (Figure 23). Most of the walleyes protected would be 5-8 years old, our primary source of broodstock walleyes.

A protected slot of 17-22 inches would protect about 21% of the harvestable year-classes of walleye in Spirit Lake, and most of these fish are broodstock walleyes (Figure 24). Many of the walleyes protected in the 17-22 inch slot are males that are slower growing and are approaching their asymptotic lengths in Spirit Lake (Table 1). It is anticipated that some male walleyes will not grow out of the protected slot of 17-22 inches in Spirit Lake.

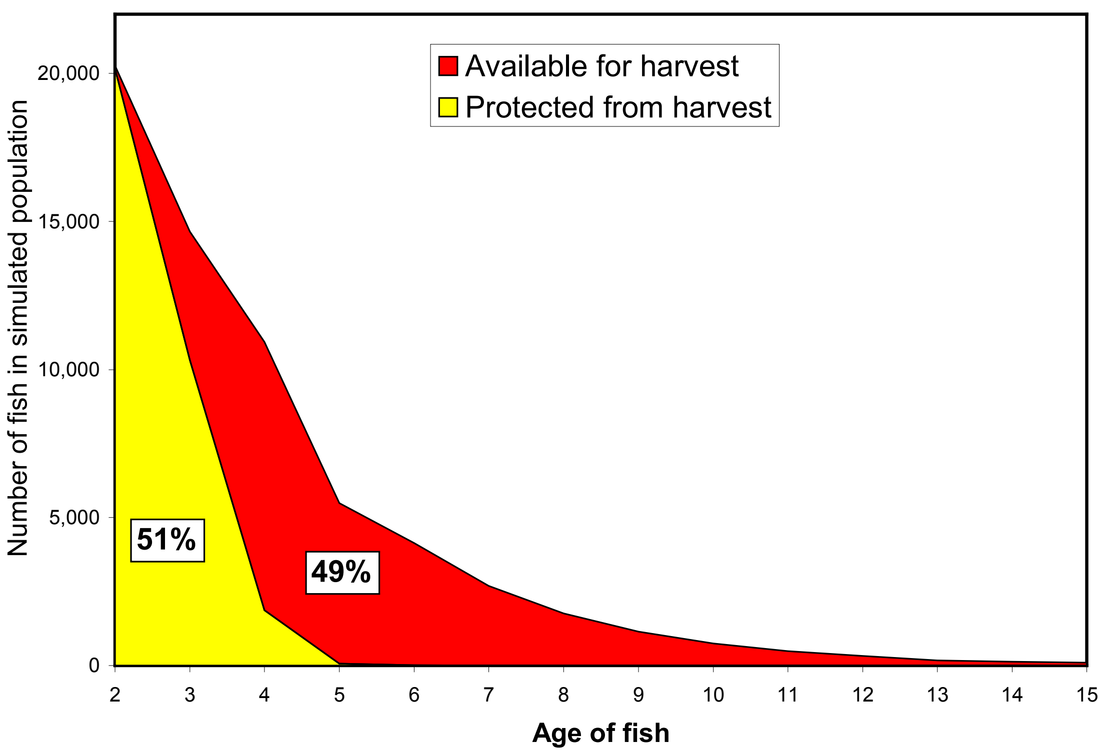

Figure 20. The number of walleyes that are currently being protected with a 14-inch minimum length limit that was implemented on Spirit Lake.

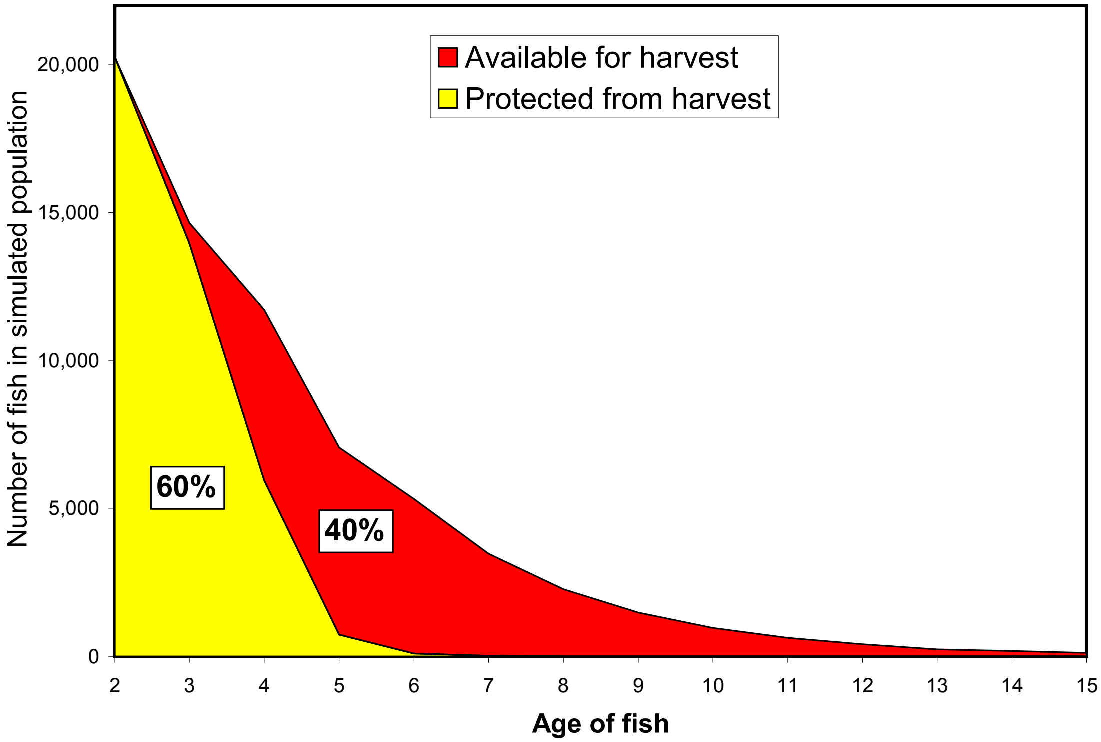

Figure 21. The potential number of walleyes that would be protected if a 16-inch minimum length limit were implemented on Spirit Lake.

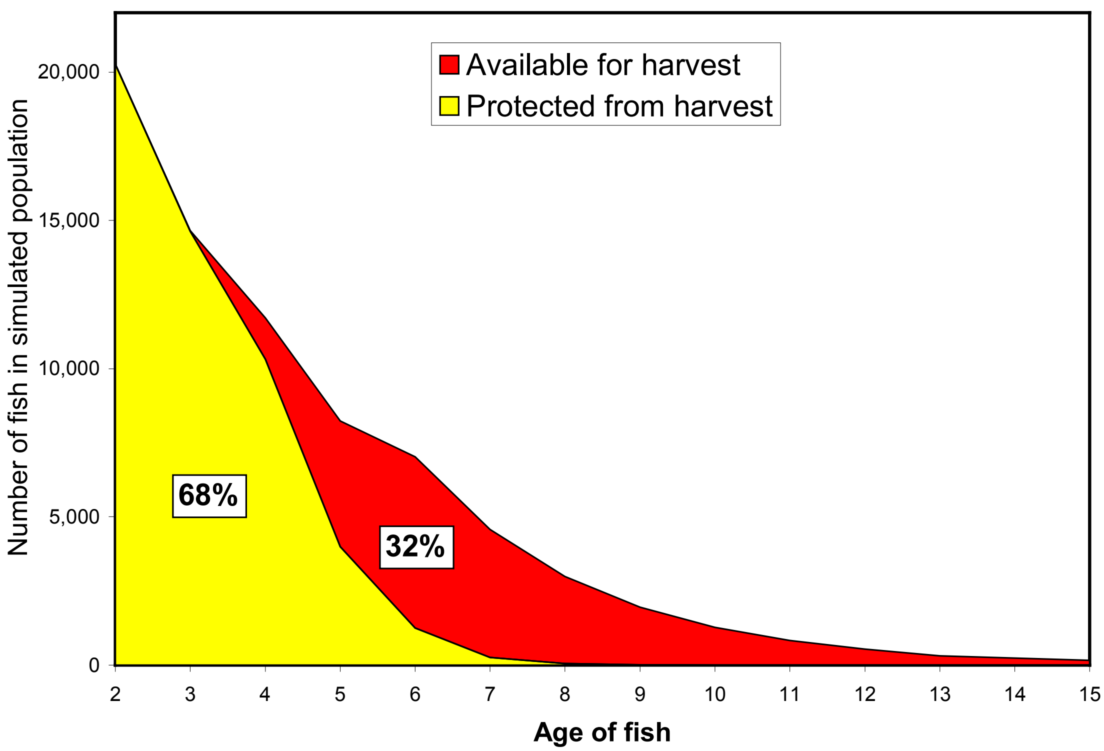

Figure 22. The potential number of walleyes that would be protected if a 18-inch minimum length limit were implemented on Spirit Lake.

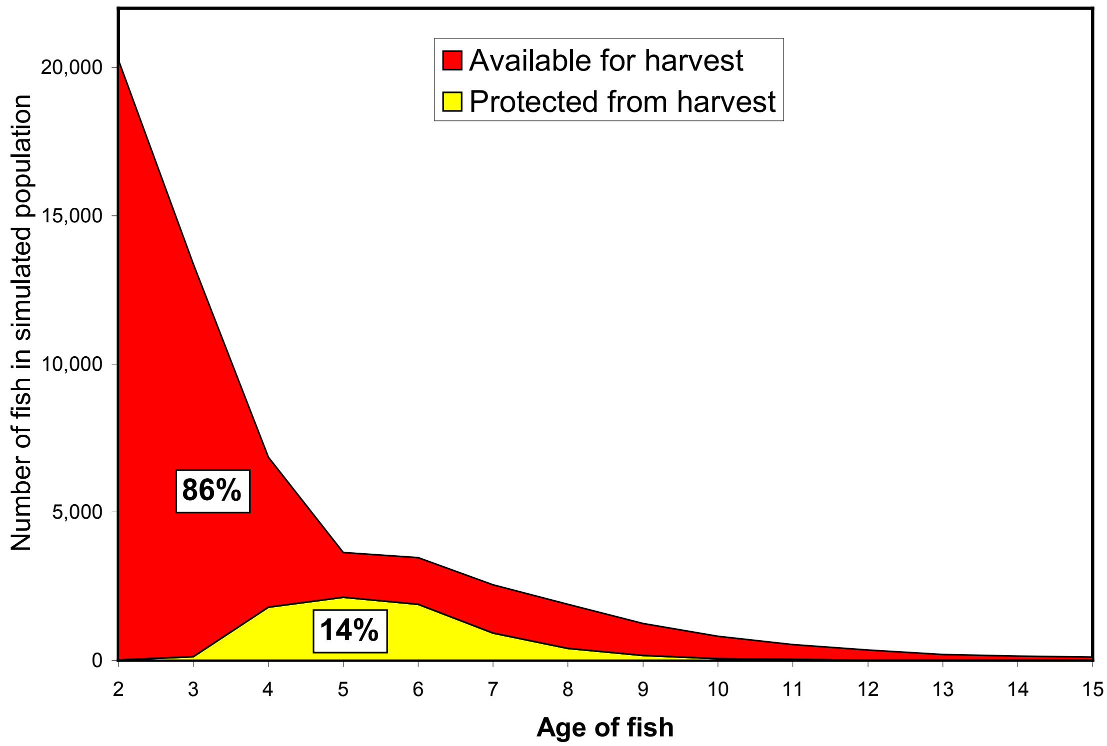

Figure 23. The potential number of walleyes that would be protected with if a 17-20 inch protected slot limit were implemented on Spirit Lake.

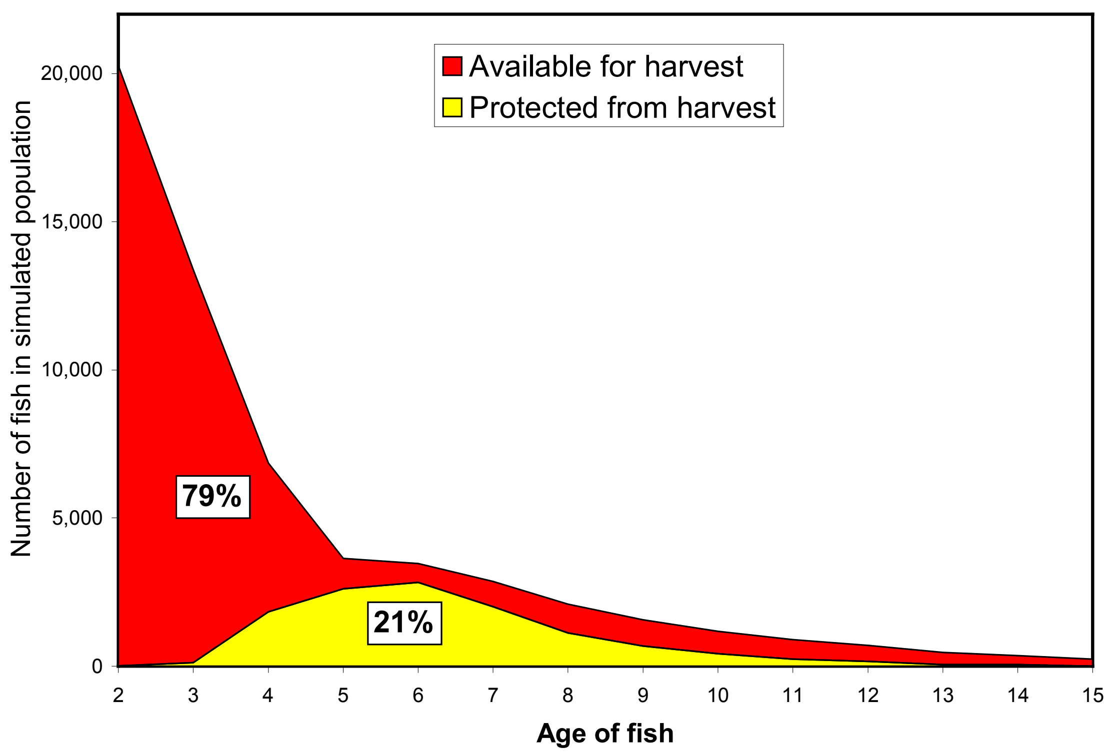

Figure 24. The potential number of walleyes that would be protected with if a 17-22 inch protected slot limit were implemented on Spirit Lake.

Total abundance and biomass of walleyes increased in each lake as the minimum length limits was increased from 14 to 16 and 18 inches (Tables 8-9). As expected, the GIFSIM model predicted harvest of walleyes would decrease as the length limit was increased. The average size of harvested walleyes also increased in each lake as the minimum length limit was increased. Each minimum length simulation showed a substantial exploitation of broodstock walleyes (around 20%), which agrees well with current exploitation estimates (unpublished data). The number of fish caught and released also increased drastically with the more restrictive minimum length limits. Loss of fish due to hooking mortality would be great however, half that of walleye taken home by the angler
.

In Spirit and the Okoboji lakes, the protected slot limits allowed anglers the opportunity to harvest more fish (mostly smaller walleyes), and decrease the number of fish that are caught and released, and the number of walleyes lost to hooking mortality (Tables 8-9). Harvest of walleye, however, would change little in Clear and Storm Lakes and would actually decrease in Blackhawk Lake if a protected slot limit were implemented. As expected, the average size of walleyes harvested would decrease in Spirit, the Okoboji lakes, and Storm Lakes if protected slot limits were implemented. However, average size of harvested walleyes would stay about the same in Clear and Blackhawk lakes.

Exploitation of broodstock walleye would decrease in all lakes but Clear Lake if a protected slot of limit were implemented, but would not change in Clear Lake. Implementation of this regulation would, however, result in an increase in the abundance of these same larger fish in all lakes but the Okoboji lakes.

Discussion

Population dynamics of broodstock walleye

Voluntary returns of VI tags from angler caught walleye varied each year but were much less than expected. Therefore, estimates based on these returns were biased due to this incomplete reporting of tagged fish (Paulik 1961). This bias was reduced by dividing the actual number of returns by the reported ratio (Ricker 1975), however, it is unknown how much bias still remained and the effect this bias had on the final estimates. VI tag retention was considered excellent and the codes on the tags were usually easy to read. Haw et al. (1990) also found excellent retention (> 95%) of VI tags implanted into clear tissue of rainbow trout.

The Jolly-Seber model was used to estimate broodstock densities since this is an open population model which accounted for recruitment and mortality. Assumptions of the Jolly-Seber model were considered to be adequately met. Broodstock densities were significantly below the study objectives in Spirit and the Okoboji Lakes, and broodstock densities would have to be doubled to reach these objectives.

At the beginning of this study, total instantaneous mortality for broodstock walleye was estimated from the descending limb of the catch curve (Ricker 1975). The critical assumption of this method is constant recruitment of broodstock walleye into the sampling gear, which was not a valid assumption. Combined data from previous years may reduce this bias (Ricker 1975) but, the extent of the remaining bias was unknown. Therefore, the Jolly-Seber

Table 8. Comparisons of simulated walleye population metrics in Spirit Lake, the Okoboji lakes, and Clear Lake for various special regulation options modeled with the General Inland Fisheries Simulator Model (GIFSIM). Currently a 14-inch minimum length limit is in place on these lakes, therefore, the 14-inch minimum length column represents current conditions for these lakes.

Average walleye population metrics	14 inch min length limit	16 inch min length limit	18 inch min length limit	17-20 inch slot limit	17-22 inch slot limit
Spirit Lake					
Total abundance	107,564	105,704	111,702	92,336	94,893
Total biomass (lbs/ac)	2.75	3.22	3.84	2.36	2.66
Broodstock abundance	11,706	15,054	19,877	11,247	13,804
Broodstock density (#/ac)	2.07	2.66	3.52	1.99	2.44
Broodstock harvest	2,565	3,298	4,354	1,809	1,110
Broodstock exploitation (%)	21.91%	21.91%	21.91%	16.08%	8.04%
Average number harvested	7,977	6,582	5,256	10,238	9,539
Average number released	6,855	9,763	12,626	1,844	3,188
Average number caught	14,833	16,345	17,882	12,082	12,727
Average number lost to hooking	1,028	1,464	1,894	277	478
Average yield (lbs/ac)	3.22	3.23	3.23	2.77	2.42
Average length harvested (inches)	18.5	19.7	21.1	16.4	16.1
Average weight harvested (lbs)	2.28	2.77	3.47	1.53	1.43
Okoboji lakes					
Total abundance	87,046	89,682	94,761	76,417	77,529
Total biomass (lbs/ac)	2.07	2.24	2.70	1.52	1.65
Broodstock abundance	10,918	12,964	17,006	5,767	8,918
Broodstock density (#/ac)	1.92	2.28	2.99	1.01	1.57
Broodstock harvest	2,392	2,841	3,083	797	785
Broodstock exploitation (%)	21.90%	21.91%	18.13%	13.82%	8.80%
Average number harvested	5,671	5,056	3,912	8,271	7,990
Average number released	7,075	8,361	10,776	1,093	1,653
Average number caught	12,746	13,417	14,688	9,364	9,643
Average number lost to hooking	1,061	1,254	1,616	164	248
Average yield (lbs/ac)	2.18	2.17	2.19	1.73	1.63
Average length harvested (inches)	18.6	19.3	20.9	15.4	15.3
Average weight harvested (lbs)	2.18	2.44	3.18	1.19	1.16
Clear Lake					
Total abundance	55,371	61,105	64,187	55,957	56,364
Total biomass (lbs/ac)	2.14	2.84	3.23	2.35	2.65
Broodstock abundance	4,594	4,619	5,847	4,212	5,691
Broodstock density (#/ac)	1.28	1.28	1.62	1.17	1.58
Broodstock harvest	675	1,011	1,281	924	808
Broodstock exploitation (%)	14.69%	21.90%	21.91%	21.93%	14.19%
Average number harvested	5,987	4,599	3,894	5,859	5,435
Average number released	942	4,131	5,653	1,119	1,979
Average number caught	6,929	8,730	9,548	6,978	7,414
Average number lost to hooking	141	620	848	168	297
Average yield (lbs/ac)	3.11	3.23	3.19	2.85	2.64
Average length harvested (inches)	17.8	19.5	20.4	17.4	17.4
Average weight harvested (lbs)	1.87	2.53	2.95	1.75	1.75

Table 9. Comparisons of current and simulated walleye population metrics in Storm and Blackhawk lakes for various special regulation options modeled with the General Inland Fisheries Simulator Model (GIFSIM). Currently a 15-inch minimum length limit is in place on these lakes. Therefore, the 15-inch minimum length column represents current conditions for these lakes.

Average walleye population metrics	15 inch min length limit	18 inch min length limit	17-20 inch slot limit	17-22 inch slot limit
Storm Lake				
Total abundance	60,850	70,695	60,146	60,987
Total biomass (lbs/ac)	3.21	4.40	3.04	3.24
Broodstock abundance	8,165	16,298	6,739	10,333
Broodstock density (#/ac)	2.64	5.26	2.18	3.34
Broodstock harvest	1,136	2,969	1,047	589
Broodstock exploitation (%)	13.91%	18.21%	15.54%	5.70%
Average number harvested	5,567	2,969	5,488	5,277
Average number released	2,423	7,744	1,746	2,461
Average number caught	7,990	10,712	7,233	7,738
Average number lost to hooking	363	1,162	262	369
Average yield (lbs/ac)	3.45	3.17	2.94	2.68
Average length harvested (inches)	17.7	20.9	16.9	16.6
Average weight harvested (lbs)	1.92	3.31	1.66	1.57
Blackhawk Lake				
Total abundance	13,164	14,195	13,624	14,130
Total biomass (lbs/ac)	2.87	3.55	3.29	3.73
Broodstock abundance	2,257	3,287	2,896	3,403
Broodstock density (#/ac)	2.29	3.33	2.93	3.45
Broodstock harvest	578	741	582	317
Broodstock exploitation (%)	25.59%	22.55%	20.10%	9.33%
Average number harvested	1,340	909	1,162	897
Average number released	249	977	556	972
Average number caught	1,589	1,886	1,717	1,869
Average number lost to hooking	37	147	83	146
Average yield (lbs/ac)	3.39	2.89	2.88	2.28
Average length harvested (inches)	19.2	20.6	19.1	19.2
Average weight harvested (lbs)	2.50	3.14	2.44	2.51

model was used to estimate the total annual survival of the broodstock walleye.

Age-growth of walleyes

McWilliams (1990) used scale samples to estimate age and growth of walleye taken during spring electrofishing samples. Scale growth, however, is not proportional to somatic growth after the fish approach asymptotic size (Weatherely and Gill, 1987; Casselman 1990). Therefore, scales may underestimate age of older walleye (McKay et al., 1990; Weatherely and Gill, 1987). In these lakes, walleye approach asymptotic length when they are between 6 and 8 years of age (Larscheid 1991). The average age of broodstock walleye from Spirit and the Okoboji Lakes was approximately 6-7 years. Scales, therefore, were not appropriate for estimating age of broodstock walleye in these lakes. In these lakes, scales were only useful for ageing walleye up to four years of age (Larscheid, 1992).

Other bony structures such as otoliths (Erickson 1983) and fin spine sections (McKay et al., 1990; Schram 1989) are preferred for estimating age of older walleye. Otoliths are the most accurate method for ageing older walleye (Schram 1989, Erickson 1983) but this method requires sacrificing the fish. Fin spine sections, therefore, were the only feasible method for determining age of broodstock walleye in these lakes.

Olson (1980) concluded that dorsal fin spines were more reliable than scales for ageing walleye, but he also emphasized that ages need to be validated due to frequent disagreement of assigned ages among readers. In these lakes, spines accurately reflected ages derived from otoliths and percent agreement of estimated ages was adequate (Larscheid 1992). Dorsal fin spines will continue to be used to estimate the age of all broodstock walleye.

Otoliths were the most reliable method for ageing walleye in these lakes (Larscheid 1992). Based on otolith samples, walleye in Spirit Lake grew significantly better than walleye from the Okoboji Lakes. This depressed growth in the Okoboji lakes, however, was primarily due to the 1986 year class of walleye. This year class was the largest ever recorded in these lakes (McWilliams and Larscheid 1992) and this year class exhibited severely depressed growth. Some individuals within this year class were still sub-legal fish at the end of their 8th growing season. This was a sobering result and it indicated that if we do derive a management strategy that will greatly increases the densities of walleyes in these lakes depressed growth may be the result.

The consequences of depressed growth may be severe. For instance, if just two years were added to the time it takes to produce a 14 inch walleye, a year class could be reduced by half with only a 30% natural mortality rate. Natural mortality, however, would more than likely increase if fish were stockpiling and growth were depressed (Serns 1978).

If the natural mortality rate increased to 40% and two years were added to the time it took to produce a 14 inch walleye, a year class would be reduced by 64%. Therefore, the protection of the 1986 year class of walleye from angling by the length limit may have actually decreased the numbers of these fish that recruited into the Okoboji broodstock population. Encouraging harvest of large year classes of small walleye by removing length limits should increase growth, decrease natural mortality, and ultimately increase the numbers of large walleye in these lakes.

Few workers have validated age of fish in age-growth studies (Beamish and McFarlane 1983), even though age validation is an essential component of any age-growth study (Weatherley and Gill, 1987). Schram (1989) was able to validate years at liberty of Floy tagged walleye using dorsal fin spines. Known age walleyes were aged using dorsal fin spines and otoliths, and assigned ages have agreed well with the known ages (unpublished data). This known age dataset is continuing to grow and this validation of the ageing structures will continue.

Evaluation of the 14 inch minimum length limit

A majority of the anglers surveyed perceived that the minimum length limit was "working" and these anglers wanted the regulation to continue in its present form. Angler compliance with these regulations was considered excellent (Larscheid 1995; McWilliams 1990).

Densities of sub-legal walleyes in these lakes did increase since the implementation of the length limit. Increased densities of sub-legal walleye by the imposition of the minimum size limit may negatively affect the walleye fishery by further decreasing growth of sub-legal walleye, thereby, increasing natural mortality, decreasing recruitment and ultimately the size structure of walleye in these lakes.

Increases in the density of sub-legal fish after imposition of a minimum size limit has been observed for largemouth bass (Farabee 1974), northern pike (Kempinger and Carline 1978) and walleye (Serns 1978). This increased density of sub-legal fish after imposition of a minimum size limit is expected and it is assumed that these fish will recruit into the fishery, thereby, increasing the density of larger walleye (Cornelius 1979). However, when length limits are imposed on walleye populations with high rates of recruitment and slow growth rates, a decrease in the density of legal fish may result (Brousseau and Armstrong 1987).

After imposition of a minimum size limit of 15 inches on walleye in Big Crooked Lake, Wisconsin, Serns (1978) found that density of sub-legal walleye increased (primarily due to recruitment of two strong year classes), growth and condition of sub-legal walleye decreased, natural mortality of sub-legal walleye increased and density of legal walleye decreased nearly three-fold. Serns (1981) also found that growth and condition of sub-legal walleye decreased in nearby Wolf Lake when a similar length limit was imposed, but also found that two strong year classes of walleye did not stockpile under the size limit as they did in Big Crooked Lake. There was no evidence of stockpiling in the three study lakes, in fact, densities of sub-legal walleyes have decreased in these lakes since the implementation of the length limit. (Why the high catch of small walleye now being reported from Spirit?)

As expected, the average size of walleye creeled in Spirit and the Okoboji Lakes increased after imposition of the minimum size limit; however, this was not necessarily an indication that the size limit increased the number of large walleye. Rather it may simply indicate that anglers were forced to harvest larger walleye. This shift in the exploitation to older walleye may ultimately decrease the number of larger walleye in these lakes. In fact, broodstock walleye already account for a substantial portion of the harvest in these lakes.

Yield and harvest of walleye have decreased in all lakes since the length limit was implemented. These results are not surprising since the length limit was designed to decrease harvest. In recent years catch rates of small walleyes have increased and many anglers are complaining about too many small fish in the system.(seems to contradict 2 paragraphs above)

Evaluation of bag limits

The decrease in the daily bag limit of walleye from 5 to 3 fish per day was ineffectual in reducing the harvest, or even spreading out the harvest to more anglers. Very few anglers caught their limit of walleye, and the harvest would have been the same if no bag restrictions were in effect. To be effective, the bag limit would have to be reduced to one walleye per day which would not be acceptable to anglers, and would greatly reduce angler participation in the fishery. The one fish over 20 inches was also ineffectual in reducing the number of large walleye harvested in these lakes. Very few anglers catch walleye over 20 inches in length, and so this regulation was not needed.

Evaluation of special regulations

The GIFSIM model fairly accurately reflected the dynamics of these walleye fisheries under a 14-inch minimum length limit. Results of the GIFSIM modeling showed that inconsistent recruitment, not the angler, was the primary reason for the low densities and harvests of walleye from these lakes (Larscheid 1995). Enhancing the consistency of recruitment could more than double the densities of walleyes and harvests of walleyes in these lakes. However, we would still be short of our objectives by relying on increased recruitment alone. Only a combination of both an increase in recruitment of young walleye and restriction on the harvest of larger walleye will produce our objectives for broodstock densities in these lakes.

The 18-inch minimum length limit is the only regulation, in combination with stabilized recruitment that would reach our objectives in Spirit and the Okoboji lakes. However, this regulation would decrease harvest an average of 34% and hooking loss would reach nearly 2,000 fish per year (36% of the total harvest). Data collected during this study plainly shows that the present 14-inch minimum length limit would never result in acceptable broodstock densities, and sacrifices our lakes ability to produce harvestable walleyes.

The 17-22 inch protected slot would increase broodstock densities in Spirit Lake by about 37% and would increase angler harvest of walleye by about 20%. This same regulation would not significantly impact broodstock densities in the Okoboji lakes, but would increase harvest of walleyes by about 41%. Exploitation of broodstock walleyes would decrease in both Spirit and the Okoboji lakes if a protected slot limit of 17-22 inches were implemented. Broodstock densities in Clear Lake and Storm lakes would also increase under a protected slot limit of 17-22 inches, although harvest and size of walleye harvested would remain about the same. Total harvest and size of walleye harvested would both decrease in Blackhawk Lake if a protected slot limit of 17-22 inches were implemented. Hooking mortality associated with the slot limit was also negligible.

In most cases, broodstock densities and harvest of walleye would be significantly increased by replacing the minimum length limits with the 17-22 inch protected slot limit. Stabilizing recruitment in combination with a 17-22 inch protected slot limit is our best bet for reaching our objectives in these lakes.

Conclusions and recommendations

The minimum lengths did not produce the desired changes in the adult walleye populations in Spirit and the Okoboji lakes. Broodstock densities were below the study objectives, in all our study lakes. Densities of broodstock walleye have to be increased 1-2 times to reach our management objectives. Exploitation of broodstock walleye was substantial and accounted for a significant portion of the total harvest of walleye, indicating that the harvest has shifted to the larger broodstock fish.

Larscheid (1995) concluded that stabilized recruitment, not implementing harvest restrictions is the key to increasing densities of walleyes in these lakes. He also concluded that recruitment alone would result in the walleye densities needed to meet our objectives. A combination of improved survival and recruitment of stocked walleye and harvest regulations is needed to increase densities of walleyes in these lakes.

The reduction in the bag limit from five to three walleye per day was not effective in either reducing or spreading out the walleye harvest to more anglers. The harvest would have been the same if the bag limits were kept at five fish per day. To be effective this regulation would have to be lowered to one fish per day, which would not be acceptable to anglers. Since this regulation was not effective, the daily bag limit should be increased to five fish per day to be consistent with the current statewide bag limit.

The one walleye over 20 inches was not effective in reducing the harvest of large walleye. The same number of large walleye would have been harvested with or without this regulation. Therefore, this regulation was not needed and should not be continued.

A protected slot limit of 17-22 inches in length is recommended to increase densities of broodstock fish in these lakes, and to allow harvest of smaller, slowing growing walleyes.

These lakes should be continually evaluated after any change in regulations are implemented. These evaluations should include creel and population surveys to help ascertain the impact of any regulations on these walleye populations.

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